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PARASITIC COPEPODS FROM BEAUFORT, NORTH CAROLINA

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Fifty-one Figures

During the summer of 1946 a survey was made of the local marine animals at Beaufort in an attempt to determine the prevalence of parasites. In this paper the results for copepods are presented. The parasitic worms, isopods, and amphipods have not yet been worked up. They will be discussed in subsequent papers. Grateful acknowledgement is made to L. B. Hayes, David Busby, and Glen E. Mathisen, who gave technical assistance during the survey. My thanks are also due to Dr. S. F. Light and Paul Illg, who read the manuscript for this paper and made constructive criticisms. Dr. George W. Wharton also suggested the use of polyvinal alcohol, which is an admirable mounting medium for small arthropods. Specimens will be deposited in the United States National Museum.

Order Copepoda
Suborder Arguloida
Family argulidae

Argulus funduli Krøyer 1863

A single individual was taken from the enteron of the butterfly fish, *Chaetodon ocellatus* Bloch, on July 18.

Suborder Cyclopoida
Family clausidiidae

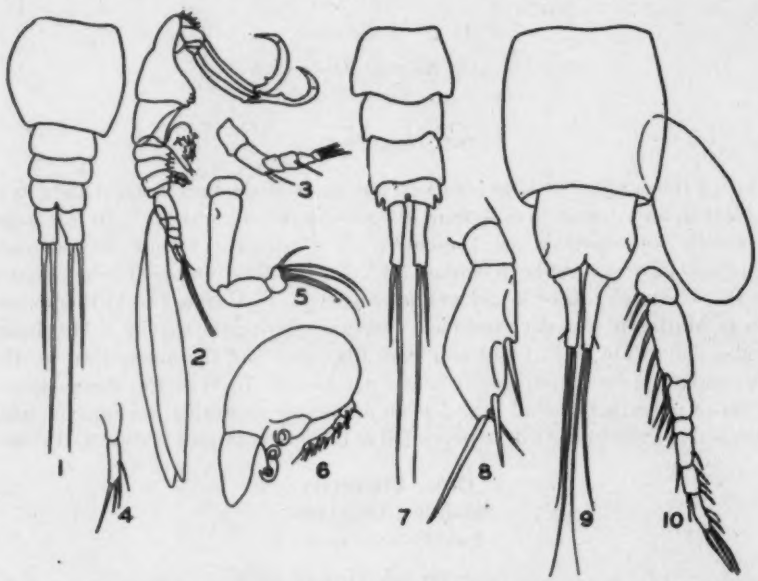
Clausidium caudatum (Say 1818)

Figs. 4–10

On June 25, 1946, eleven specimens of *Callianassa major* Say were examined. These had from 0 to 13 clausidiums, a total of 83, single females or pairs, and an average of 7.5 each. The copepods occurred on the gills, walking legs, swimmerets, and some swam in the water. Seventy-eight clausidiums were mounted and among these 18 of the males were clinging to the posterior ends of the females.

As Wilson (1921) did not have specimens of this species, it is described and figured. Light and Hartman (1937) gave an excellent review of the genus Clausidium but apparently did not have specimens of *C. caudatum*.

Female.—First thoracic segment fused with head and this cephalothorax is about as long as wide (.49–.52 mm.). Its postero-lateral angles are produced. Segments 2–5 of the thorax are separate; the first three are four times as wide as long and 2 and 3 have the postero-lateral angles produced; segment 5 is twice as wide as long and rounded posteriorly. The genital segment is slightly wider than long (.15–.13 mm.) and has rounded lateral margins. It is only slightly



FIGS. 1–10. *Macrobrachinus felichthys:* 1, abdomen of female; 2, lateral view of female; 3, first antenna of female; *Clausidium caudatum* (Say); 4, fifth foot of male; 5, second antenna of female; 6, first leg of female; 7, abdomen of male; 8, fifth foot of female; 9, abdomen of female and right egg mass; 10, first antenna of female.

covered by thoracic segment 5. The abdomen (9) is 2-segmented; the first segment is longer and wider (.13–.16 mm.) than the second (.09–.09) which is cleft posteriorly. The caudal furcae are about six times as long as their average width and terminate in two setae, the lateral one of which is two-thirds as long as the inner; there is also a small lateral seta near the distal end. The egg strings (9) are attached to the sides of the genital segment; each contains 15–25 eggs.

The first antenna (10) consists of 7 setose segments; the second segment is longest, the fourth shortest. The second antenna (5) is 3-segmented; the distal segment bears 4 long and 1 short setae. The first legs (6) are peculiarly modified;

the exopod is 3-segmented; the endopod is biramous and bears a hook and 3 suckers on the median ramus. Legs 2–4 are biramous and all rami are 3-segmented. The fifth legs (8) are 2-segmented; the distal segment bears 1 terminal and 3 lateral setae; the former is the longest. Total length, 1.2 mm.; width of carapace, .53 mm.; length of egg strings, .28 mm.

Male.—Cephalothorax somewhat longer than wide (.3–.27 mm.); the second and third thoracid segments wide and angulate laterally; segment 4, twice as wide as long, overlapping segment 5; segment 5, half the width of 4. Abdomen 4-segmented (7); caudal rami, linear but otherwise similar to those of female. Antennae, mouth parts, and fifth legs (4) similar to those of the female. Total length, .57 mm.; width of carapace, .27 mm.

Family MYICOLIDAE

Pseudomyicola glabra n. sp.

Figs. 11–20

This species occurred on the gills and mantle of *Modiolus demissus* (Dillwyn), *Ostrea virginica* Gmelin, *Atrina rigida* Dillwyn, *Pecten irradians* Lamarck, *Noetia ponderosa* Say, and *Mytilus edulis* L. at Beaufort, N. C., during May and June, 1946.

Female.—Head separate from first thoracic segment; segments 2–5 grow gradually narrower posteriorly: urosome (11, 12) half as long as metasome; caudal rami more than twice as long as anal segment, slender, tapering, with two short terminal setae and two on the lateral and dorsal surfaces. Genital segment with five little ridges on sides near anterior margin; anal segment with minute spinules around posterior margin. First antenna (14) with a sharp, strong spine projecting posteriorly from the proximal segment; 6-segmented; the first segment longest, the proximal three wider than the distal three. Second antenna (16) with the third segment longest, narrowest, and curved; the second segment shortest, and the proximal segment widest; a strong terminal claw present. The swimming legs are all biramous and each ramus is 3-segmented. Fifth foot (17, 18), 2-segmented, broad, flat and thickened along one margin; with four distal setae, two rows of 7 and 8 denticles along the middle of the thin margin, and 11 spines across the anterior surface. Egg strings (19, 20) contain 5–12 eggs arranged in groups or in a lineal series. Total length 2.23 mm.; width, .53 mm.; length of egg string, .33–55mm.

Male.—Similar to female, but smaller. The fifth legs (15) are relatively smaller, about half as long as those of the female; they are 2-segmented and have 5 denticles on the medial distal angle of the terminal segment. The lobes on the genital segment have a small seta on the posterior margin, and the denticles on the posterior margin of the anal segment are longer than those in the female (13). Total length, 1.76 mm.; width, .47 mm.

This species is readily distinguished from Yamaguti's (1936) species, *P. astreae*, by the absence of denticles on the caudal rami, the presence of 3 segments in the second antenna, two rows of minute denticles across the genital segment of the

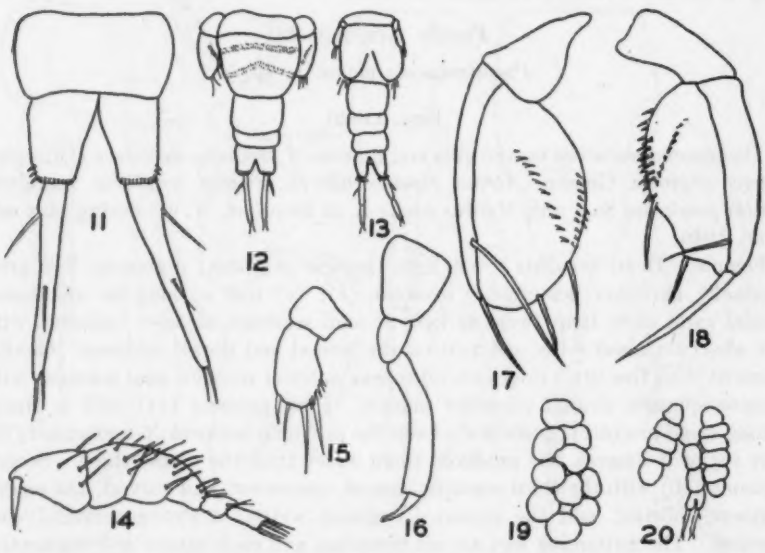
female (12). The first antennae and the appendages posterior to the second antenna are much like those of Yamaguti's species. The name given refers to the comparatively smooth abdominal furcae.

Myicola tageli n. sp.

Figs. 21–25

Specimens of this copepod were taken from the gills and mantle of *Tagelus gibbus* (Spengler) during May and June, 1946, at Beaufort, N. C.

Female.—Body somewhat flattened; head and first thoracic segment, separate

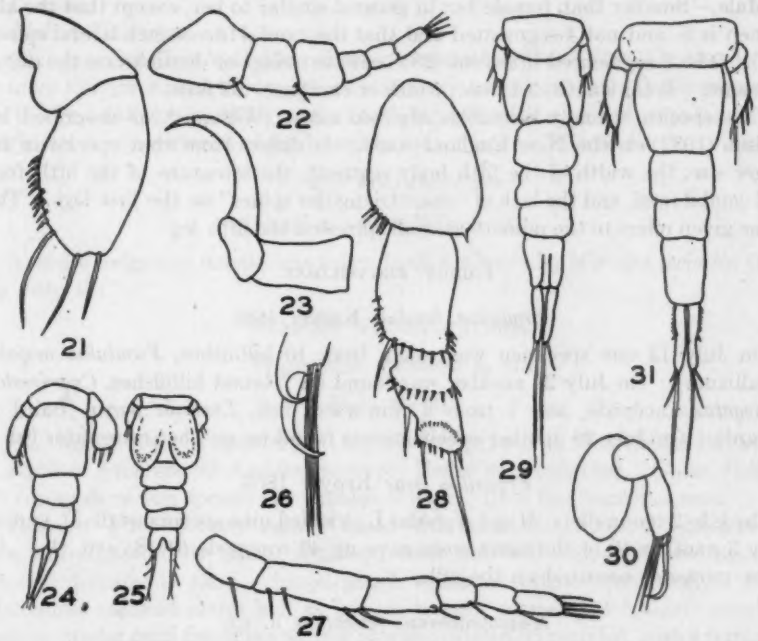


FIGS. 11–20. *Pseudomyicola glabra:* 11, 12, abdomen of female; 13, abdomen of male 14, first antenna of female; 15, fifth foot of male; 16, second antenna of female; 17, 18 fifth feet of females; 19, 20, egg strings and abdomen.

segments 1–4 slightly narrower posteriorly; segment 5 almost as wide as 4, narrow, one-third as long as wide; urosome half as long as metasome. Caudal rami (24), twice as long as anal segment, slender, one-eighth as wide as long, with setae on the lateral margins $\frac{1}{3}$ and $\frac{1}{2}$ of distance from bases. First antenna (22), 6-segmented; the proximal segment widest and longest, the three distal segments narrower. Second antenna (23), slender, 3-segmented, with a single claw at the distal end. The swimming legs are all biramous, with three segments in each ramus. The fifth foot (21) is 2-segmented, the distal segment broad, ellipsoidal, armed with three terminal setae and a double row of about 11 small spines on the median margin. Total length, 2.2 mm.; width, .6 mm.

Male.—Smaller than female; genital segment (25), swollen. The appendages are similar to those of the female, except that a pair of maxillipeds is present and the fifth foot is smaller. Total length, 1.49 mm.; width, 145 mm.

This species differs from the others that occur in clams on the Atlantic coast of North America in its slender caudal rami, the character of the fifth foot, and those of the first and second antennae.



FIGS. 21–31. *Myicola tageli:* 21, fifth foot of female; 22, first antenna of female; 23, second antenna of male; 24, abdomen of female; 25, abdomen of male. *Myicola spinosa:* 26, tip of second antenna of female; 27, first antenna of male; 28, fifth foot of male; 29, abdomen of male; 30, second antenna of male; 31, abdomen of female.

Myicola spinosa n. sp.

Figs. 26–31

Specimens of this copepod were taken from the gills and mantle of *Tagelus gibbus* (Spengler), *Dosinia discus* Reeve, and *Venus mercenaria* L., during May and June, 1946, at Beaufort, N. C.

Female.—Body somewhat flattened, head separate from first thoracic segment and a little longer than wide; thoracic segments 1–4 gradually narrower but 5 is somewhat wider than 4. Metasome longer than urosome; caudal rami a little longer than anal segment. First antenna 6-segmented; the second segment,

longest; distal segment of the 3-segmented second antenna bearing 2 claws and 3 setae (26). The caudal rami (31) bear about 13 small spines on the proximo-lateral margin, a larger spine at the end of this row, and 3 setae at the distal end. The 2-segmented fifth foot bears five spines on the apex and distal-lateral half and has three rings of small denticles distally and a short row of small spines on the proximal segment. The egg strings contain about 800 eggs. Total length 3.0 mm.; width of carapace, .77 mm.; length of egg strings, .62 mm.

Male.—Smaller than female but in general similar to her, except that the abdomen is 5- and not 4-segmented and that the caudal furcae lack lateral spines (29). The 2-segmented fifth foot (28) bears two rings of denticles on the distal segment. Total length, 2.1 mm.; width of carapace, .52 mm.

This species strongly resembles *Myicola major* (Williams), as described by Wilson (1932) on the New England coast. It differs from that species in its larger size, the width of the fifth body segment, the armature of the fifth foot and caudal rami, and the lack of "stout triangular spines" on the first legs. The name given refers to the numerous small spines on the fifth leg.

Family ERGASILIDAE

Ergasilus funduli Krøyer 1863

On July 13 one specimen was taken from 10 killifishes, *Fundulus majalis* (Walbaum). On July 24 another was found on 7 broad killifishes, *Cyprinodon variegatus* Lacépède, and 1 from a rain-water fish, *Lucania parva* (Baird & Girard). On July 26 another specimen was found on another rain-water fish.

Ergasilus lizae Krøyer 1863

On July 2 ten mullets, *Mugil cephalus* L., yielded nine specimens (0–3), and on July 3 another 10 of the same hosts gave up 40 copepods (0–18; ave., 4). All these parasites occurred on the gills.

Macrobrachinus felichthys n. sp.

Figs. 1–3

This copepod was common on the gills of the gafftopsail catfish, *Felichthys felis* (L.), on July 31 (0–40; ave. 13.3) and August 14 (1), and one was taken from the gill of the sea catfish, *Galeichthys milberti* (Cuvier & Valenciennes) on July 31, 1946.

Female.—Body elongate (2), about four times as long as broad; head fused with first thoracic segment and projecting ventrally to form a blunt sucking beak; suture line behind the beak. Thoracic segments 2–4 decrease a little in width posteriorly; fifth segment four times as wide as long; the genital segment is barrel-shaped and a little narrower posteriorly (1). Abdomen (1) made up of three segments that are about twice as wide as long; caudal rami 1½ times as long as third segment, tipped with two setae, one 4 times and the other 8 times as long as ramus. Egg strings (2) one-tenth longer than body, slender; about three eggs in cross section, and about 100 in one string.

First antennae (3), 6-segmented, the second segment longest. Second antenna (2) more than three-fourths as long as body; 3-segmented; the first segment one-third as long as the second; the third five-sixths as long as the second, curved, armed with a short spine at its inner distal third; terminal claw half as long as third segment. Swimming legs 1–4 biramous; rami 3-segmented, except the endopod of leg 1, which is 2-segmented. No fifth leg is present; it is represented by a single seta. Total length, 1.08 mm.; width, .27 mm.; length of egg string, 1.42 mm.

Male.—Unknown.

This species differs from *Macrobrachinus punctatus* Hesse (1872) in that it has a more slender cephalothorax, shorter and stouter caudal rami, fewer segments in the first antenna, a spine on the third segment of the second antenna, fewer segments in the endopod of leg 1, and in that it lacks a fifth foot.

Family BOLOLOCHIDAE

Artacolax setiger Wilson 1911

A single ovigerous female was taken from a silverside, *Menidia menidia* (L.), on July 13.

Suborder NOTODELPHYOIDA

Notodelphys monoseta n. sp.

Figs. 36–40

On May 25, 1946, at Beaufort, N. C., in a dredge haul off Shackleford Banks, at a depth of 8 meters, 22 *Ascidia interrupta* Heller were collected. These yielded 19 copepods of this species (10 females, 9 males) from the branchial sacs.

Female.—First thoracic segment fused with head; second and third segments free and separated by lateral sinuses; fourth and fifth segments fused and expanded dorsally to form a brood pouch which is widened posteriorly. First abdominal segment about half as long as second; segments 2–5 about equal in length; caudal rami five times as long as wide, ciliated on margins, with 4 terminal setae. First antenna 12-segmented, segment 8 the longest. Second antenna 3-segmented, with a strong hook and three terminal setae. All swimming legs are biramous and the rami all 3-segmented. The fifth legs (37) are very small, twice as wide as long, 2-segmented, the basal and distal segment each bear one seta, the latter bears the seta on a projection. Length, 5.3 mm.; width of carapace, .75 mm.

Male.—Similar to female, but the fifth foot (36) is smaller. On the ventral side of the first abdominal segment there are two flat plates, each of which bears two setae (40). The first antennae are 13-segmented (39); the second are 3-segmented and armed with a terminal hook (38). Length, 2.0 mm.; width of carapace, .55 mm.

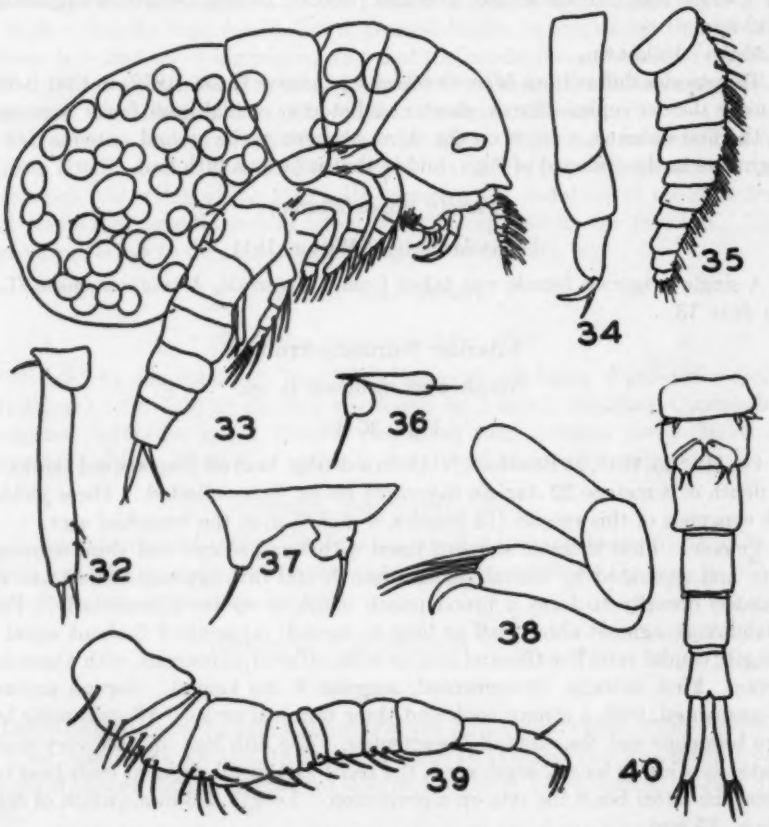
This species is distinguished from *Notodelphys agilis* Thorell by the single seta on the distal segment of the fifth foot and by the difference in the number of antenna segments. The specific name refers to the former character.

Family DOROPYGIDAE

Doropygus laticornis Wilson 1932

Figs. 32–35

Specimens were taken from the branchial cavities of *Perophora viridis* Verrill by Gloria Grimes on June 13, 1944. From 15 specimens of *Styela partita* (Stimpson)



FIGS. 32–40. *Doropygus laticornis:* 32, fifth foot of female; 33, lateral view of female; 34, second antenna of female; 35, first antenna of female. *Notodelphys monoseta:* 36, fifth foot of male; 37, fifth foot of female; 38, second antenna of male; 39, first antenna of male; 40, abdomen of male.

that were dredged from a depth of 5 meters off Shackleford Banks on May 25, 1946, the writer collected 8 doropygids. From 39 specimens of *Styela plicata* collected from the piles on the railroad bridge and the Duke University pier on May 23 and 24, 1946, 4 doropygids were taken, but from five ascidians of the

same species dredged from a depth of 5 meters off Shackleford Banks on May 25, 1946, 63 doropygids were collected. On May 27, 1946, 5 styelas from the Town Marsh yielded 6 doropygids. These results indicate that the ascidians near the open sea are more heavily parasitized than those in the Beaufort Estuary.

Suborder CALIGOIDA
Family CALIGIDAE

Eirgos anurus Bere 1936

From spade fishes, *Chaetodipterus faber* (Broussonet), the following collections were made: 5 fishes on July 5, 7 (0–4); 3 fishes on July 8, 0; and 5 fishes on July 31, 5 (0–3).

Caligus schistonyx Wilson 1905

Three chalimi of these parasites were taken from the caudal fin of an agujon, *Strongylura acus* (Lacépède), on July 19. An adult female was taken in a plankton net at the surface of Beaufort Channel on July 9.

Lepeophtheirus edwardsi Wilson 1905

A single female was collected from the skin of a flounder, *Paralichthys dentatus* (L.), one of two examined on June 26.

Family ANTHOSOMIDAE

Lernanthropus chlamydotus Wilson 1944

Three weakfishes, *Cynoscion regalis* (Holbrook), examined on June 30 yielded 6 of these copepods; another examined on July 3 furnished 5 more.

Lernanthropus sp.

A single female was collected from a flounder, *Paralichthys dentatus* (L.), on June 24.

Lernanthropus pupa Burmeister 1833

Five spade fishes, *Chaetodipterus faber* (Broussonet), examined on July 5 yielded seven of these copepods (0–4), all from the gills.

Lernanthropus pomatomi Rathbun 1884

This copepod was found on three hosts: 3 bluefishes, *Pomatomus saltatrix* (L.), gave 3 on July 16; 2 pigfishes, *Orthopristis chrysopterus* (L.), 1 on July 26; and 2 weakfishes, *Cynoscion regalis* (Holbrook), 2 on July 23.

Family EUDACTYLINIDAE

Nemesis pallida Wilson 1932

One male was taken from a spot-fin ground shark, *Carcharhinus limbatus* (Müller & Henle), on August 5.

Family PSEUDOCYCNIDAE

Pseudocycnus buccatus Wilson 1922

From 5 Spanish mackerel, *Scomberomorus maculatus* (Mitchill), 3 of these copepods were taken on July 16.

Noetiphilus n. gen.

Pseudocycnidae. Female. Head free from first segment of thorax; all thoracic segments separate; body more than seven times as large as wide. Abdomen, 1-segmented. First antenna short, 5-segmented; second antenna stout and uncinate; maxillipeds stout, with terminal claw. Legs biramous; each ramus 2-segmented; fifth legs represented by a narrow plate that bears three setae.

Male.—Unknown. This genus differs from Pseudocycnus in that legs 1–4 all have 2-segmented rami.

Type.—*Noetiphilus elongatus* n. sp.

Noetiphilus elongatus n. sp.

Fig. 45

A single female (45) was taken from the gills of a clam, *Noetia ponderosa* Say, on July 26, 1946, from near the breakwater on Shark Shoal, Beaufort, N. C.

Female.—Head and thoracic segments about equal in width; thoracic segments about equal in length; fifth segment twice as long as fourth. Abdomen tapering posteriorly, smooth, unsegmented, and ending in two caudal rami, each of which is tipped with three short setae. First antenna 5-segmented, the second segment longest; second antenna stout with terminal claw; maxillae flat and rugose; maxillipeds stout with a transverse terminal claw. Legs 1–4, short, biramous; each ramus 2-segmented; fifth legs represented by narrow plates which bear three setae. Length, 2.6 mm.

Family DICHELESTHIIDAE

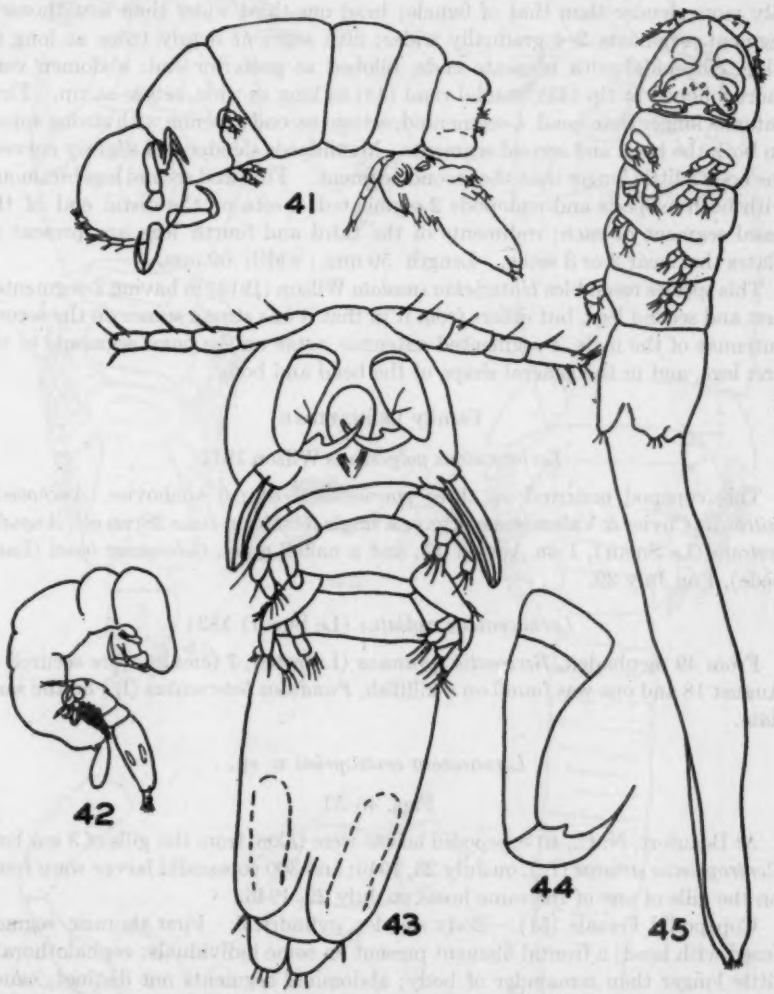
Hatschekia prionoti n. sp.

Figs. 41–44

A single pair was collected from a gill of a Carolina sea robin, *Prionotus carolinus* (L.), July 10, 1946. The specimens were first mounted in damar (42) and later remounted in polyvinal alcohol (41, 43, 44). In the change the small egg sac (42) was lost from the abdomen of the female.

Female.—Body robust, cylindrical 5 times as long as wide, posterior end of abdomen truncate. Four thoracic segments hard to distinguish but visible. The first segment slightly shorter than second; the fourth and fifth about equal in length and shorter than first and second segments; the fifth segment lobate on either side; sixth segment fused with abdomen and enclosed within the fifth. Caudal furcae minute, slightly longer than wide, and with three terminal and one lateral setae. First antennae 4-segmented, setose at tip; second antennae with a stout basal segment, a tapering second segment, and a strongly curved terminal

hook (44) which is two-thirds as long as the second segment and has a tooth on the inner surface near the base. The maxillipeds have a short terminal spine



FIGS. 41–45. *Hatschekia prionoti:* 41, 42, female and male; 43, ventral view of male; 44, tip of second antenna of female. *Noetiphilus elongatus:* 45, ventral view of female.

and two slender preceding segments that are about equal in length. The first and second swimming legs are biramous and each ramus is 2-segmented; both have a seta on the lateral angle of the basal segment; the exopods are twice as

long as the endopods. The egg sac (42) measured .15 mm. long. Length 1.0 mm.; width 0.2 mm.

Male.—Body robust, cylindrical, nearly five times as long as wide; proportionally more slender than that of female; head one-third wider than first thoracic segment; segments 2–4 gradually wider; fifth segment nearly twice as long as wide, ellipsoidal with truncate ends, bilobed at posterior end; abdomen very short, bilobed at tip (43); caudal rami (43) as long as wide, setose at tip. First antenna longer than head, 4-segmented, setose; second antenna with strong spines on both the hook and second segment. Maxillipeds slender and slightly curved; the hook a little longer than the second segment. First and second legs biramous, with both exopods and endopods 2-segmented, a seta on the distal end of the basal segment of each; rudiments of the third and fourth legs are present as plates that bear 2 or 3 setae. Length .59 mm.; width .09 mm.

This species resembles *Hatschekia insolata* Wilson (1913) in having 2-segmented first and second legs, but differs from it in that it has strong spines on the second antennae of the male, 4-segmented antennae, setae on the basal segments of the first legs, and in the general shape of the head and body.

Family LERNAEIDAE

Lernaeenicus polyceraus Wilson 1917

This copepod occurred on three species of hosts: 6 anchovies, *Anchoviella mitchilli* (Cuvier & Valenciennes), gave a single female on June 28; an eel, *Anguilla rostrata* (Le Sueur), 1 on August 17; and a naked goby, *Gobiosoma bosci* (Lacépède), 1 on July 29.

Lernaeenicus radiatus (Le Sueur) 1824

From 49 menhaden, *Brevoortia tyrannus* (Latrobe), 7 females were secured on August 18 and one was found on a killifish, *Fundulus heteroclitus* (L.) on the same date.

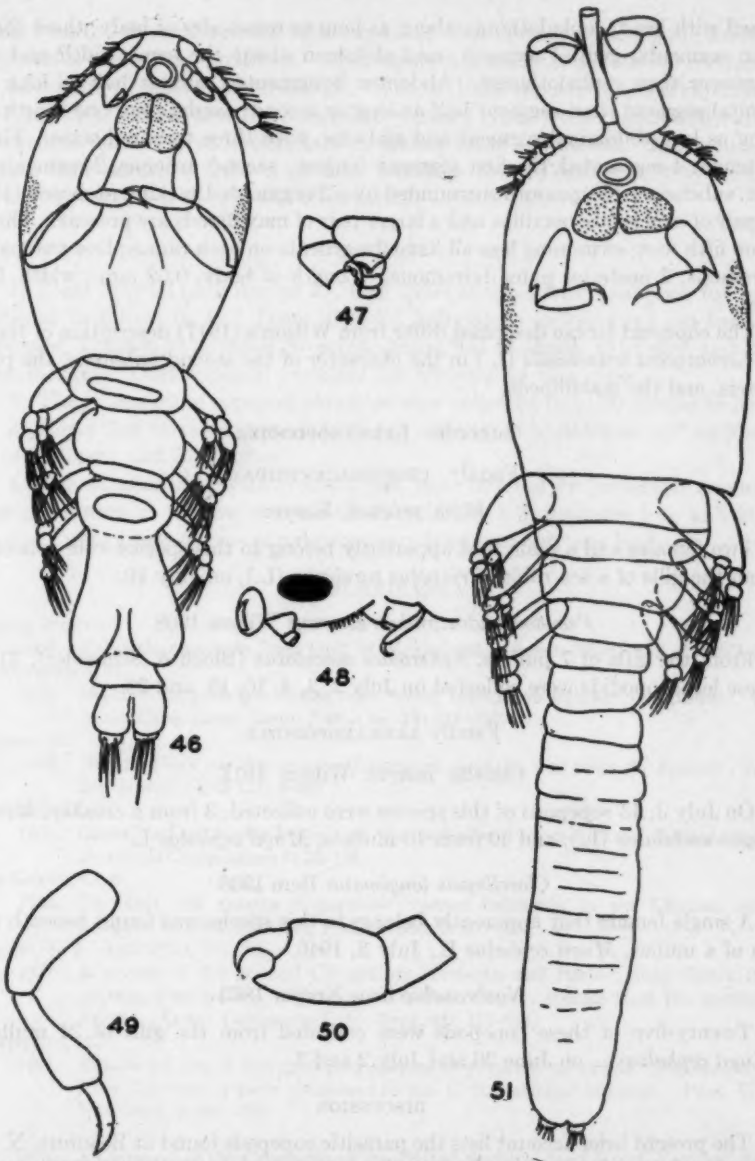
Lernaeocera centropristi n. sp.

Figs. 46–51

At Beaufort, N. C., 40 copepodid larvae were taken from the gills of 3 sea bass, *Centropristus striatus* (L.), on July 23, 1946; and 300 copepodid larvae were found on the gills of one of the same hosts on July 29, 1946.

Copepodid Female (51).—Body slender, cylindrical. First thoracic segment fused with head; a frontal filament present on some individuals; cephalothorax a little longer than remainder of body; abdominal segments not distinct; caudal rami short, armed with 3 short setae. First antenna 4-segmented, the proximal segment longest. Second antenna, 2-segmented, the distal segment flat and subchelate. A circular proboscis surrounds the mouth. The rami of the swimming legs are 2-segmented; first two pairs, biramous; last two pairs, uniramous (51); no fifth leg is present. Length of body, 0.8 mm.; width, 0.2 mm.

Copepodid Male.—Body (46) somewhat flattened. First thoracic segment



FIGS. 46–51. *Lernaeocera centropristi*, copepodid stages: 46, male; 47, second antenna and mouth tube; 48, second antenna mouth tube, eye, and maxilla of female; 49, maxilla of female; 50, second antenna of male; 51, female.

fused with head; cephalothorax about as long as remainder of body; three thoracic segments, genital segment, and abdomen about the same width and all narrower than cephalothorax. Abdomen 2-segmented, almost half as long as genital segment; first segment half as long as second; caudal rami one fourth as long as last abdominal segment and globular, with three terminal setae. First antenna, 4-segmented, the first segment longest; second antenna 2-segmented, flat, subchelate (50); mouth surrounded by a 2-segmented sucking proboscis (48). A pair of subchelate maxillae and a larger pair of maxillipeds are present. There is no fifth foot; swimming legs all have 2 segments on each ramus; first two pairs biramous, 2 posterior pairs uniramous. Length of body, 0.62 mm.; width, 0.2 mm.

The copepoid larvae described differ from Wilson's (1917) description of those of *Lernaeocera branchialis* (L.) in the character of the second antennae, the proboscis, and the maxillipeds.

Suborder LERNAEOPODOIDA

Family CHONDRACANTHIDAE

Blias prionoti Krøyer

Two females and a male that apparently belong to this species were collected from the gills of a sea robin, *Prionotus carolinus* (L.), on July 10.

Pseudochondracanthus diceraus Wilson 1908

From the gills of 7 puffers, *Spheroides maculatus* (Bloch & Schneider), 31 of these lernaeopodids were collected on July 2, 3, 4, 10, 13, and 29.

Family LERNAEOPODIDAE

Clavella inversa Wilson 1913

On July 3, 43 copepods of this species were collected; 3 from a croaker, *Micropogon undulatus* (L.), and 40 from 10 mullets, *Mugil cephalus* L.

Clavellopsis longimana Bere 1936

A single female that apparently belongs to this species was found beneath the fin of a mullet, *Mugil cephalus* L., July 3, 1946.

Naobranchia lizae Krøyer 1863

Twenty-five of these copepods were collected from the gills of 21 mullets, *Mugil cephalus* L., on June 26 and July 2 and 3.

DISCUSSION

The present brief account lists the parasitic copepods found at Beaufort, N. C., during the summer of 1946 and describes eight new species. Of the latter 4 are from clams, 1 from ascidian, and 3 from fishes. Thirty species were found on 39 species of hosts. Of these 23 occurred on only one species of host, 5 on 3, 1 on 2,

and 1 on 6. Several animals were examined that carried no copepod parasites. Species of hosts that "produced" copepods were distributed as follows: crustacean 1, ascidians 4, clams 9, and fishes 25. Wilson (1932) reported *Caligus rapax* from 31 species of fishes, and these included various types from sharks and rays to flounders, but such wide distribution among hosts is unusual. Most students agree that parasites show a general tendency toward host-specificity and, as would be expected, the present observations support this view.

SUMMARY

1. From May 23 until August 27, 1946, 2350 animals were examined for parasites at Beaufort, N. C. These included individuals as follows: 1 sea turtle, 4 sponges, 3 corals, 31 annelids, 86 echinoderms, 445 molluscs, 451 fishes, and 2255 crustaceans. Only copepod parasites are reported in this paper.

2. Thirty species of copepod parasites were collected from 39 species of hosts.

3. Hosts that carried copepods included 1 species of crustacean, 4 of ascidians, 8 of molluscs, and 25 of fishes.

4. The number of species of hosts that were infested by particular species of parasites were as follows: crustacean 1, ascidians 1–3, molluscs 1–6, and fishes 1–3. Twenty-two species of parasites were found on only one host.

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LATITUDE, LONGITUDE, AZIMUTH,—DETERMINED BY SIMPLE AND ACCURATE METHODS

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Figures 1–5

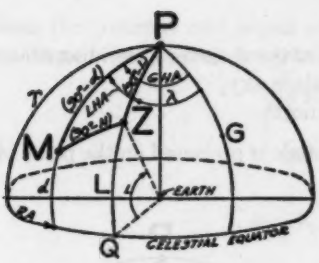

Fig. 1. Equator System

Declination, pole distance, latitude, GHA, LHA, etc.

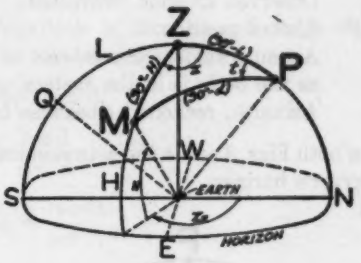

Fig. 2. Horizon System

Zenith, zenith distance, altitude, azimuth, etc.

GENERAL NOTATION

The following abbreviations and definitions apply to the astronomical triangle, the PZM triangle, shown in Figs. 1–4.

L	Latitude of observer's position (on land or at sea) north or south of the celestial equator.
λ	Longitude of observer's position east or west of the Greenwich meridian.
DL	Difference in latitude.
DL_0	Difference in longitude.
DR	Dead reckoning position of the ship or airplane.
ZT	Zone time, or standard time.
ZD	Zone description.
G	Greenwich (reference point).
γ	"Vernal equinox" (reference point for stars).
GCT	Greenwich civil time.
GHA	Greenwich hour angle, measured westward from the Greenwich meridian to the sun (or star).
LCT	Local civil time.
LHA	Local hour angle, reckoned from the observer's meridian westward from 0° to 360°.
t	Meridian angle, reckoned east or west of the observer's meridian according as the body is in the eastern or western sky.

SHA	Sidereal hour angle, measured westward from the vernal equinox to the star.
RA	Right ascension (360°—SHA).
d	declination = position of the sun (or star) north or south of the celestial equator.
p	polar distance (90°—d).
H	Altitude = angle of elevation to the sun (or star).
z	Zenith distance (90°—H).
Hs	Uncorrected altitude given by sextant or surveyor's transit.
Ho	Observed altitude (corrected).
LOP	Line of position.
Z	Azimuth angle, reckoned east or west of the observer's meridian according as the body is in the eastern or western sky.
Zn	Azimuth, reckoned clockwise from north.

In both Figs. 3 and 4 the astronomical triangle is projected on the plane of the observer's horizon.

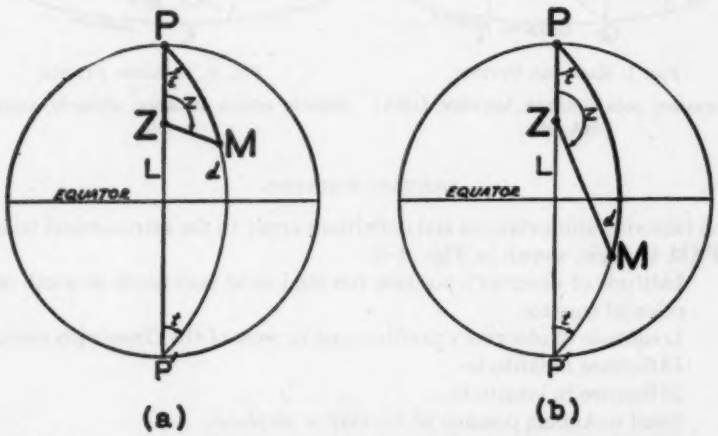

FIG. 3. BODY IN EASTERN SKY; OBSERVER IN NORTHERN HEMISPHERE

(a) L and d same name (both positive) (b) L and d opposite name (L positive, d negative)

LATITUDE

Well known methods of determining latitude are: (1) by meridian altitude of the sun (noon sight); (2) by altitude of Polaris; (3) by meridian altitude of a star.

Another method applying to either hemisphere will now be presented. In Fig. 4, we have the PZM triangle in which arc MF (= R) is drawn from M perpendicular to arc PZ at F, thus forming right triangles MFP and MFZ. Two cases (a) and (b) arise depending upon whether the perpendicular MF

falls inside or outside of the triangle. It will be seen that (K − L) is positive in (a) and negative in (b); however, only the first case is shown in Fig. 4.

Applying Napier's rules to Fig. 4, we get

$$\sin R = \sin t \cos d, \tag{1}$$

$$\sin K = \frac{\sin d}{\cos R}, \tag{2}$$

$$\cos (K - L) = \frac{\sin H}{\cos R}, \tag{3}$$

Since the cosecant and secant are reciprocals of the sine and cosine respectively these formulas may be rewritten as follows:

$$\csc R = \csc t \sec d, \tag{4}$$

$$\csc K = \frac{\csc d}{\sec R}, \tag{5}$$

$$\sec (K - L) = \frac{\csc H}{\sec R}, \tag{6}$$

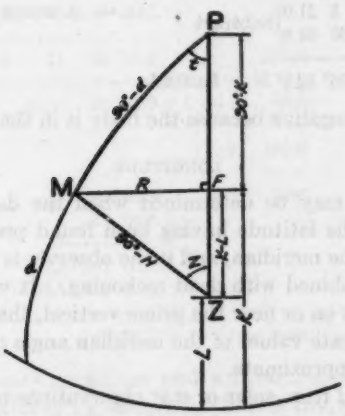

FIG. 4.

It follows that L can be computed if t, d and H are known. The quantity (K − L) may be positive or negative. It is *positive* if the body is in the northern sky; *negative* if the body is in the southern sky. K has the sign of d.

It will be shown later that favorable positions of the body for accurate latitude determination occur when it is on or near the observer's meridian. In the example which follows, the star Procyon is in the southern sky shortly after it has crossed the observer's meridian. (The time of meridian transit of all navigational stars for any date is found in the nautical almanac.)

EXAMPLE 1. On April 10, 1946, at zone time $18^h\ 40^m\ 12^s$, an aviator finds the corrected altitude to the star Procyon to be 59° 27.2′. The DR position of the plane is 36° 20′ N, long. 48° 00′ W. The Greenwich hour angle (GHA) of Procyon is 49° 26.5′ and its declination is 5° 21.8′. It is required to calculate the correct latitude by means of Eqs. 4–6. The work form in connection therewith is believed to be self explanatory.

GHA 49° 26.5′
Long. 48 00.0W

t 1 26.5W (approx.)

Eqs. 4–6. Work Form No. 1
A = log cosecant × 100 000
B = log secant × 100 000

		Add	*Subtract*	*Subtract*
H	59° 27.2′ →	.....	.....	A 6489
t	1 26.5 →	A 159930		
d	5 21.8 →	B 191 →	A 102932	
R		A 160121 →	B 14 →	B 14
K	5 21.9	Subtract ..... ←	A 102918	
(K − L)	− 30 31.0	..... ←		B 6475
L	35° 52.9′ N = Latitude.			

NOTE: (K − L) is negative because the body is in the southern sky.

LONGITUDE

Time or longitude may be determined when the declination, altitude and latitude are known, the latitude having been found previously from pointings to bodies on or near the meridian, and if the observer is on a ship or plane, this latitude would be combined with dead reckoning. It will be shown later that observations on bodies on or near the prime vertical, that is, east or west of the observer, lead to accurate values of the meridian angle *t*, or the longitude, even when the latitude is approximate.

The meridian angle *t* from solar or star observations may be calculated accurately, and without rules as to quadrant, from the formula

$$\sec^2 \tfrac{1}{2}t = \frac{\sec s \sec (s - z)}{\sec d \sec L}, \qquad (7)$$

in which t is the meridian angle; s is ½(z + d + L); z is the zenith distance (90°—H); d is the declination; H is the altitude; L is the latitude.

Eq. 7 is unique in that it requires the use of only one trigonometric function, the *secant*, whose logarithm is always positive and greater than unity. Eq. 7 was derived from

$$\cos^2 \tfrac{1}{2}A = \frac{\sin S \sin (S - a)}{\sin b \sin c}, \qquad (8)$$

which applies to a spherical triangle whose angles are A, B, C with opposite sides a, b, c. Letting A = t; a = 90° − H; b = 90° − d; c = 90° − L; and substituting secants for reciprocals of the cosine, Eq. 7 leads to Eq. 8, which represents a solution of the astronomical triangle (Fig. 2).

EXAMPLE 2. At sea, Aug. 26, 1946, at $7^h\ 30^m$ am, the corrected altitude to the sun's center is 24° 12.0′. The DR position of the ship is lat. 28° 34′ N, long. 44° 20′ W. The GHA of the sun is 337° 01.5′ and its declination is 10° 33.6′. It is required to calculate the longitude by means of Eq. 7.

Eq. 7. Work Form No. 2
B = log secant × 100 000

H	24° 12.0′	
z	65 48.0	B
d	10 33.6 →	742
L	28 34.0 →	5638
2)	104 55.6	6380 →
s	52 27.8 →	21519
(s − z)	− 13 20.2 →	1187
(s − d)	41 54.2	22706
Sum	28 34.0 = L (ck.)	6380 ←
		2) 16326
½t	34° 02.4′ ....← B	8163
t	68 04.8 E	
LHA	291 55.2	
GHA	337 01.5	
	45 06.3 W = Longitude.	

NOTE: The preliminary additions and subtractions can be checked before entering the table (a table of log secants). This is true since (s − z) + (s − d) always gives L.

AZIMUTH

(A) Given d, L, H, to find Z.
(B) Given d, L, to find Z when the body is at elongation.
(C) Given d, L, t, to find Z when the body is near elongation.

The precise determination of the meridian or the true azimuth of a line is, or should be, an integral part of all important land survey and development operations.

(A) Given d, L, H, to find Z.

Replacing t with Z and interchanging H and d in Eq. 7 leads to Eq. 9 which follows.

$$\sec^2 \tfrac{1}{2}Z = \frac{\sec S \sec (S - p)}{\sec H \sec D}, \qquad (9)$$

in which Z is the azimuth angle reckoned east or west of the observer's meridian according as the body is in the eastern or western sky; S is $\frac{1}{2}(p + H + L)$; p is the polar distance $(90° - d)$; d is the declination; H is the altitude; L is the latitude.

Like Eq. 7, Eq. 9 involves only one trigonometric function, the secant. Since the angle Z would never be near 0°, but about 90°, $\frac{1}{2}Z$ would be around 45°. Hence Eq. 9 is satisfactory for all the cases that arise.

EXAMPLE 3. On July 31, 1946, at $10^h\ 00^m$ pm eastern standard time the corrected altitude to the star Arcturus, in the western sky, is 34° 35.0′. The observer's position is lat. 35° 10′ N, long. 79° 40′ W. The star's declination is 19° 27.8′ N. It is required to calculate the azimuth by means of Eq. 9.

Eq. 9. Work Form No. 3
B = log secant × 100 000

		B
d	19° 27.8′	
p	70 32.2	
H	34 35.0 →....	8444
L	35 10.0 →....	8752
2)	140 17.2	17196 →
S	70 08.6 →....	46895
(S − p)	− 0 23.6 →....	1
(S − H)	35 33.6	46896
Sum	35 10.0 = L (ck.)	17196 ←
		2) 29700
½Z	44° 44.0′....← B	14850
Z	89° 28.0′ NW; Z_n = 270° 32′.	

NOTE: The preliminary additions and subtractions can be checked before entering the table (a table of log secants). This is true since (S − p) + (S − H) = L.

(B) Given d, L, to find Z when the body is at elongation.

The most favorable position for accurate azimuth determination occurs when the star appears to be moving vertically for some time. In this position it is said to be at east or west elongation according as the body is farthest east or west of the observer's meridian. In these positions the PZM triangle becomes a

right triangle in which the angle at M (at the star) equals 90°. Hence at the instant of elongation we have

$$\csc Z = \frac{\sec d}{\sec L} \quad (10); \qquad \sec t = \frac{\tan d}{\tan L} \quad (11); \qquad \csc H = \frac{\csc L}{\csc d} \quad (12)$$

Since the cosecant is always greater than unity, Eq. 10 is impossible unless d is numerically greater than L; and since H is always positive, Eq. 12 is impossible unless L and d have the same sign.

Hence for any latitude, elongation does not occur except for those "circumpolar" stars where d is greater and of the same sign (name) as L.

Only d and L are necessary, hence Eq. 10 alone will give the azimuth when the time of elongation is known. Eq. 11 is useful in predicting the time at which elongation will occur on any given date. Eq. 12 is of no practical use, since azimuth in the region of elongation may remain almost constant for large variations in t and H. A study of the sequence of quantities in H.O.[1] 214 discloses this fact in a striking manner.

The telescope of the transit (vernier reading 0° 00′) is directed to the star a few minutes ahead of the predicted time of elongation. Then with the instrument set in this position, the vertical cross wire is kept centered on the star by means of the tangent screw of the lower clamp. When horizontal motion ceases and the star moves vertically, plunge the telescope and mark a point about 200 ft. ahead. This marked line makes an angle Z (given by Eq. 10) with true north. If the star was at east elongation, true north is to the left; if at west elongation, true north is to the right.

(C) Given d, L, t, to find Z when the body is near elongation.

With the increasing facilities of radio the standard or zone time can be known accurately at any date. Hence knowing d, L and the local longitude, one may determine Z independently of H, and with greater accuracy, if the star is within the region of elongation.

TABLE A (p. 24) gives for a few circumpolar stars an approximate range of values of t, H and Z at various latitudes. Thus to an observer at latitude of 35° N, the value of Z to the star Capella varies from about 56.6° to 54.7° as t ranges from 35° to 73° and H from 61.5° to 35.4°. Hence within this region a small error in t will cause no appreciable error in Z.

Applying Napier's rules to each of the right triangles in Fig. 4, and reducing, we get

$$\tan K = \tan d \sec t \quad (13); \qquad \cot Z = \frac{\cot t \sec K}{\csc (K - L)} \quad (14)$$

The angle Z may approach 90°, but never 0°, hence the *cotangent* was selected instead of the *tangent*, in deriving Eq. 14. For the convenience of applying Eqs. 13 and 14, the form, "Work Form No. 4" was devised.

As an alternate solution, one may use Eqs. 15–18, given below, which are derived by applying Napier's rules to Fig. 4. It will be seen that Eqs. 15–17 are

[1] Hydrographic Office of the U. S. Navy, Washington, D. C.

the same as Eqs. 4–6. This set of formulas by the aid of "Work Form No. 5" are adapted to a table of log secants and cosecants compiled and published by the author to every 0.2′ of arc. The solution, although apparently longer, is believed to be much easier than that by Eqs. 13–14. Example 4 which follows illustrates both methods.

$$\csc R = \csc t \sec d \quad (15); \qquad \csc H = \sec R \sec (K - L) \quad (17)$$

$$\csc K = \frac{\csc d}{\sec R} \quad (16); \qquad \csc Z = \frac{\csc R}{\sec H} \quad (18)$$

TABLE A

Changes in H and Z during time intervals at various Latitudes

L (North)	t	H	Z (From North)
CAPELLA, d = 45° 57′			
1°	63°–76°	19.8°–10.4°	40.9°–43.3°
5	62 –80	22.8 –10.5	41.7 –44.1
10	59 –85	28.5 –10.6	42.7 –44.8
15	54 –90	35.5 –10.7	43.6 –45.0
20	50 –90	41.7 –14.2	45.5 –45.8
25	47 –90	47.2 –17.7	48.4 –46.8
30	41 –90	54.4 –21.1	51.7 –48.1
35	35 –73	61.5 –35.4	56.6 –54.7
40	28 –56	68.1 –49.5	64.5 –62.4
VEGA, d = +38° 44′			
1	65°–78°	20.0°–10.0°	49.0°–51.1°
5	60 –81	26.4 –10.2	49.2 –51.7
10	57 –85	31.9 –10.1	50.6 –52.4
15	52 –89	38.8 –10.0	52.3 –52.6
20	46 –90	46.4 –12.3	54.7 –53.2
25	39 –90	54.5 –15.3	58.1 –54.2
30	32 –90	62.4 –18.1	63.4 –55.4
35	29 –49	66.6 –51.1	72.8 –70.1
ALDEBARAN, d = +16° 24′			
1	50°–79°	38.4°–10.8°	69.6°–73.4°
5	42 –81	47.4 –10.0	71.0 –74.1
10	32 –82	58.2 –10.4	74.8 –74.9
15	25 –83	65.9 –10.7	83.0 –75.6
REGULUS, d = +12° 14′			
1	50°–80°	39.2°–10.0°	75.3°–78.0°
5	36 –80	53.7 –10.8	76.5 –78.7
10	25 –81	65.4 –10.8	83.0 –79.6
15	45 –82	36.6 –10.7	86.0 –80.3

L (South)	t	H	Z (From South)
ACRUX, d = −62° 48′			
−1°	60°–70°	14.0°– 9.8°	23.9°–25.7°
−5	60 –77	17.7 –10.3	24.4 –26.7
−10	55 –87	24.3 –10.3	24.1 –27.4
−15	55 –90	28.8 –13.5	25.1 –27.8
−20	52 –90	34.6 –17.8	25.8 –28.5
−25	53 –90	38.6 –22.1	27.7 –29.3
−30	50 –90	44.3 –26.5	29.1 –30.5
−35	50 –90	38.6 –30.7	31.7 –31.9
−40	47 –90	54.1 –34.9	34.5 –33.6
−45	44 –90	59.4 –39.3	38.3 –35.8
−50	40 –75	65.0 –49.3	43.6 –42.3
−55	55 –62	61.6 –55.5	51.3 –50.0
CANOPUS, d = −52° 40′			
−1	65°–74°	15.7°–10.5°	35.0°–36.5°
−5	61 –80	21.3 –10.1	34.9 –37.5
−10	60 –86	26.0 –10.3	35.9 –38.1
−15	56 –90	32.3 –11.8	36.7 –38.5
−20	54 –90	37.4 –15.8	38.3 –39.2
−25	49 –90	44.2 –19.6	39.9 –40.3
−30	47 –90	49.1 –23.4	43.0 –41.6
−35	45 –90	53.9 –27.1	46.9 –43.2
−40	38 –74	61.3 –39.7	51.4 –49.5
SIRIUS, d = −16° 38′			
−1	50°–80°	38.4°– 9.9°	69.6°–73.4°
−5	44 –81	45.4 –10.0	71.5 –74.1
−10	32 –82	58.2 –10.4	74.8 –74.9
−15	30 –83	61.1 –10.8	82.9 –75.6

EXAMPLE 4. During the evening of July 1, 1946, a pointing is made to the star Vega in the eastern sky. The horizontal motion of the transit is clamped at $21^h\ 02^m\ 20^s$, at the instant the vertical cross hair is on Vega. The GHA of Vega is 46° 21.0′, and its declination is 38° 43.9′. It is required to calculate the azimuth for an observer at lat. 32° 05.4′ N, long. 96° 20.0′ W by means of (a) Eqs. 13–14 and (b) Eqs. 15–18.

(a) Eqs. 13–14. Work Form No. 4

							Add	*Add and Subtract*
	$21^h\ 02^m\ 20^s$	7/1/46		d	38° 43.9′	→	*l* tan 9.90420	
ZD	6			t	49 59.0	→	*l* sec 0.19178	→ *l* cot 9.92407
GCT	3 02 20	7/2/46		K	51 16.8	←	*l* tan 0.09598	→ *l* sec 0.20376
	0° 38.5′			L	32 05.4			0.12783
	45 37.5	(From NA)		(K–L)	19 11.4		→.....	*l* csc 0.48320
	5.0			Z	66 11.6 NE		.....←	*l* cot 9.64463
GHA	46 21.0			Z_n	293° 48.4′ = Azimuth.			
Long.	96 20.0W							
t	49 59.0E							

(b) Alternate Solution. Eqs. 15–18. Work Form No. 5
A = log cosecant × 100 000; B = log secant × 100 000

			Add	*Subtract*	*Add*	*Subtract*
t	49° 59.0′	→	A 11585			
d	38 43.9	→	B 10786	→ A 20365.5		
R			A 22371	→ B 9587	→ B 9587	→ A 22371
K	51 16.8	.....	← A 10778.5			
L	32 05.4					
(K – L)	19 11.4	→	.....		B 2483	
H					A 12070	→ B 18508.5
Z	66 11.6 NE	.....				← A 3862.5

Z_n 293° 48.4′ = Azimuth.

NOTE: K takes the same quadrant as t and the sign of d;
Z is acute if (K − L) is positive;
Z is obtuse if (K − L) is negative.

APPENDIX—Most Favorable Conditions for Accuracy

Certain fundamental relations applying to a spherical triangle are:

$$\sin H = \sin d \sin L + \cos d \cos L \cos t, \tag{19}$$

$$\cos H \cos Z = \sin d \cos L - \cos d \sin L \cos t, \tag{20}$$

$$\sin t \cos d = \sin Z \cos H, \tag{21}$$

$$\sin M \cos d = \sin Z \cos L. \tag{22}$$

Eq. 19 follows from the law of cosines; Eqs. 21 and 22 are applications of the law of sines. Eq. 20 is unusual. It is derived in Hosmer's Practical Astronomy, 3rd Ed., p. 256, John Wiley and Sons, Inc.

(A) Latitude

To evaluate the exact effect on L of any error in t we may differentiate L with respect to t, the quantities H and d being taken as constant. Accordingly we have from Eq. 19

$$0 = \sin d \cos L \frac{dL}{dt} + \cos d\left(-\sin L \cos t \frac{dL}{dt} - \cos L \sin t\right) \quad (23)$$

$$\frac{dL}{dt}(\sin d \cos L - \cos d \sin L \cos t) = \cos d \cos L \sin t \quad (24)$$

From Eqs. 20, 21 and 24, we get

$$\frac{dL}{dt} = \tan Z \cos L. \quad (25)$$

This shows that L is entirely independent of t when $Z = 0°$, or when the body is on the observer's meridian. Favorable positions occur when the body is near the meridian, and all the more so for large latitudes.

Referring to Example 1, it follows that by Eqs. 21 and 25 an error in t of 10′ will cause an error in L of only 0.3′.

Differentiating L with respect to H while treating t and d as constant, we get by Eqs. 19 and 20,

$$\frac{dL}{dH} = \sec Z. \quad (26)$$

This shows that the most favorable position is on or near the meridian, but that an error in H causes an equal error in L.

(B) Time or Longitude

Inverting Eq. 25 we have

$$\frac{dt}{dL} = \frac{1}{\tan Z \cos L} = \frac{\sec L}{\tan Z}. \quad (27)$$

This shows that at the instant when $Z = 90°$, $\frac{dt}{dL} = 0$; hence when the body is in that position an error in L has no effect on t. In other words the most favorable position of the body is on the prime vertical. It also shows that this statement is all the more true for observers nearer the equator. Thus for a latitude of 30°; suppose Z is within 2.5° of the prime vertical, that is, Z_n lies between 87.5° and 92.5° or between 267.5° and 272.5°, then $\frac{dt}{dL}$ is less than 0.05. Hence if the DR latitude is in error by the amount of 20′ the calculated value of t will not be more than 1′ in error. Actually the latitude should be known rather

closely if it is determined from a previous or nearly simultaneous sight to a body on or near the meridian.

Longitudes may therefore be determined most exactly when pointings to the sun or star are on or near the prime vertical, even though the assumed latitude is somewhat erroneous.

Differentiating t with respect to H while treating L and d as constant, we have by Eqs. 19 and 21,

$$\frac{dt}{dH} = -\csc Z \sec L. \qquad (28)$$

This shows that when $Z = 90°$, csc Z is least and hence $\frac{dt}{dH}$ is least, for any L, and all the more so when L is small. The most favorable position of the body is therefore on the prime vertical. The negative sign indicates that t decreases as H increases, but if Z is obtuse, this sign is reversed.

Using the data of Example 2 and applying Eqs. 21 and 27, it follows that $\frac{dt}{dL} = 0.02$, hence an error in L of 1° causes an error in t of only 1′. But Eq. 28 shows that $\frac{dt}{dH} = 1.1$, hence an error in H causes about the same error in t.

Digressing for a moment we see by inverting Eq. 28 that $\frac{dH}{dt} = -\frac{1}{\csc Z \sec L}$. Hence the computed value of H (called H_c) is most favorably determined, in so far as an error in t is concerned, when the body is near the meridian, and all the more so, for large latitudes. This is of interest particularly in connection with the LOP method of determining latitude and longitude.

(*C*) *Azimuth*

From Eq. 27 and a cyclic change of letters we have

$$\frac{dZ}{dH} = \frac{\sec H}{\tan M} \qquad (29)$$

This shows that an error in H causes a negligible effect in Z when the angle at M (at the sun or star) becomes 90°, that is, when the body is at elongation; which cannot be true except when d is greater than L, or when the observer star is circumpolar.

It will follow that when d is less than L, or is in opposite hemisphere, the most favorable position of the body for azimuth determination will depend on both H and the angle at M. The relative error in Z is smallest when M is large and H is small.

From Eq. 22 it is seen that the maximum value of M occurs simultaneously with the maximum value of Z, that is, when the body is on or near the prime vertical, or east or west of the observer. This position of the body may or may not be near the horizon; in case it is, altitudes should not be less than about 15° on account of the uncertainty of the horizontal refraction.

Using the data of Example 3 and applying Eqs. 22 and 29, it follows that $\frac{dZ}{dH} = 0.7$, hence an error in H of 3′ causes an error in Z of 2′.

Interchanging the letters t and Z in Eq. 27, we have

$$\frac{dZ}{dL} = \frac{\sec L}{\tan t}. \tag{30}$$

This shows that the least error in Z due to an error in L will occur when the body is on the 6-hour circle (t = 90°).

Combining Eqs. 20 and 21 to eliminate cos H and dividing the resulting expression by cos d, we get

$$\sin t \cos Z = \tan d \tan L - \sin L \cos t. \tag{31}$$

Differentiating Z with respect to t while d and L remain constant we get

$$\frac{dZ}{dt} = \frac{\cot t \cos Z - \sin L}{\csc^2 Z}. \tag{32}$$

The least error in Z due to an error in t occurs when the numerator of Eq. 32 equals zero, or when

$$\sin L = \cot t \cos Z. \tag{33}$$

Eq. 33 is true only if the angle at M equals 90°, or when the body is at elongation. Therefore the most favorable position of the body for azimuth determination, in so far as a possible error in t (and H) is concerned, occurs at elongation.

MISCELLANEOUS EXERCISES

EXAMPLE 5. This exercise is an adaptation of Example 2 in Vol. IV of H.O. 214, as follows: During twilight, March 1, 1940, a plane was in DR position, lat. 30° 21.0′ N; long. 92° 05.0′ W; true course, 240°; ground speed, 180 knots, when the following observations were taken with bubble octant (IC 0.0′) for fix of position at the time of observation of the star Capella.

STARS	ZT	GHA	d	H_o
Hamal	18^h 29^m 52^s	136° 10.3′	23° 10.8′	50° 26.4′
Procyon	18 39 53	55 34.9	5 22.5	47 07.7
Capella	18 44 51	92 48.3	45 56.4	74 05.6

The latitude and longitude at any instant (taking into account the run of the plane) may be read directly from the Mercator chart (Fig. 5), or computed by means of the following formulas: DL = Distance × cos C; DL_o =

$\frac{\text{Distance} \times \sin C}{\cos L_m}$; in which "Distance" = ground speed × time, C = true course, L_m = approx. mid-latitude.

The time elapsed between Hamal and Capella sights is 15 minutes, and the ground distance traveled is 45 miles.

DR latitude at time of Capella sight is 30° 21.0′ − 0° 22.5′ = 29° 58.5′.

DR longitude at time of Capella sight is 92° 05.0′ W + 0° 45.0′ = 92° 50.0′ W.

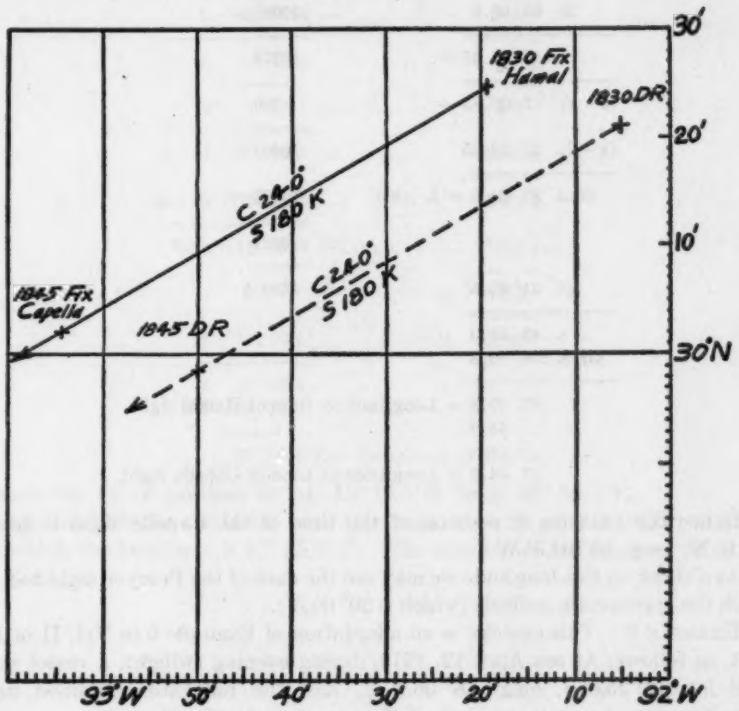

FIG. 5.

GHA (Capella)	92° 48.3′
DR Longitude	92 50.0W
t	0 01.7E

It is seen that Capella was very near the meridian. It will be treated as a meridian sight. Hence L = d − (90° − H) = 30° 02.0′. This quantity represents the latitude of the fix, and it agrees with that given in H.O. 214.

The longitude of the fix will be determined from the data of the Hamal sight together with the calculated latitude which equals 30° 02.0′ + 22.5′ = 30° 24.5′

Eg. 8. Work Form No. 2
B = log secant × 100 000

H_o 50° 26.4′ (Hamal)

		B
z	39 33.6	
d	23 10.8 →.....	3656
L	30 24.5 →.....	6427
2)	93 08.9	10083→
s	46 34.45 →.....	16278
(s − z)	7 00.85 →.....	326
(s − d)	23 23.65	16604
Sum	30 24.5 = L (ck.)	10083←
		2) 6521
½t	21° 55.5′ .....← B	3260.5
t	43 51.0	
GHA	136 10.3	
	92 19.3 = Longitude at time of Hamal sight.	
	45.0	
	93 04.3 = Longitude at time of Capella sight.	

Hence the 1845 fix of position at the time of the Capella sight is lat. 30° 02.0′ N, long. 93° 04.3′ W.

As a check on this longitude we may use the data of the Procyon sight together with the appropriate latitude (which is 30° 09.5′).

EXAMPLE 6. This exercise is an adaptation of Example 6 in Vol. II of H.O. 214, as follows: At sea April 12, 1919, during evening twilight, a vessel was in DR lat. 12° 25.0′ S, long. 88° 06.1′ E, and the navigator obtained nearly simultaneous observations of the following stars for fix of position.

STAR	ZT	GHA	d	H_o
Procyon.....	18h 24m 30s	271° 53.9′	5° 22.7′	72° 19.3′
Regulus.....	18 25 00	234 46.0	12 15.7	45 34.6
Rigel.....	18 25 30	308 16.7	−8 16.5	54 09.9

GHA (Procyon) = 271° 53.9′ W = 88° 06.1′ E
DR Longitude = 88 06.1 E
t = 0 00.0

Hence L = d − (90° − H) = −12° 18.0′ = latitude of the fix.

The longitude of the fix will be calculated from this latitude combined with the data of the Rigel sight.

Eq. 8. Work Form No. 2
B = log secant × 100 000

H_o 54° 09.9′ (Rigel)

z	35 50.1		B
d	−8 16.5	→.....	454.5
L	−12 18.0	→.....	1009
2)	15 15.6		1463.5→
s	7 37.8	→.....	386
(s − z)	−28 12.3	→.....	5489.5
(s − d)	15 54.3		5875.5
Sum	−12 18.0 = L(ck.)		1463.5←
		2)	4412
½t	18° 06.4′	.....← B	2206
t	36 12.8		
GHA	308 16.7		
	87 56.0 E = Longitude of the fix.		

Hence the fix of position is lat. 12° 18.0′ S, long. 87° 56.0′ E.

Using this latitude combined with the Regulus sight gives t = 37° 18.2′E, from which the longitude is 87° 55.8′ E. The results are the same as those in H.O. 214.

A NEW MACROMIA FROM NORTH CAROLINA

By M. J. Westfall, Jr.

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Six Figures

While serving as counselor and director of nature study at Camp Carolina near Brevard, N. C., in 1941, I collected some dragonflies on the Little River nearby. In my paper of 1942[1] under *M. alleghaniensis*, I told of collecting nine males and one female of a species of *Macromia*. In that paper I stated that they were a rather curious lot, and that they had some of the characters for *alleghaniensis* and some for *illinoiensis* as given in the key by Walker.[2] Since that time I have had the opportunity of making a careful study of the genus, and have dissected and studied the genitalia of one of these specimens and specimens of other related species.

Dr. Walker's key has been very useful in this study, as well as the detailed information found in Williamson's paper.[3] When Walker's key is used, this species will come out in the third rubric as *alleghaniensis* or *illinoiensis*, but one will have difficulty in assigning the specimens to either. In 1941 I identified them tentatively as *alleghaniensis* since more of the characteristics of the latter species were present in the Little River specimens. It was stated that further study might result in the change of this determination. Now enough characters have been found to designate sufficiently the Little River specimens as a new species which is herein described.

Macromia margarita[4] new species

Measurements (millimeters)—Holotype ♂: total length, 74; abdomen (incl. apps.), 54; first tibia, 9; hind tibia, 13.5; hind femur, 14.5; hind wing, 47. Allotype ♀: total length, 78; abdomen 57; first tibia, 9; hind tibia, 14; hind femur, 16; hind wing, 52. Paratypes eight ♂'s: total length, 72–76; abdomen, 49–54; first tibia, 8.5–9; hind tibia, 13–14; hind femur, 13–14.5; hind wing 45.5–48.

Male: head with compound eyes and occiput dark brown; frontal vesicle entirely black; frons black with blue-green metallic reflections, a pair of small yellow dorsal spots separated from each other by at least their width, and two larger lateral spots which are twice the size of the dorsal spots or larger; postclypeus bright yellow except for a very narrow edging of brown on its anterior margin; anteclypeus, brown; labrum yellowish brown with a distal brown border; lateral faces of mandibles yellow; labium yellowish brown; rear of head black

[1] Entom. News **53**: 100, 1942.
[2] Canad. Entom. **69**: 12, 1937.
[3] Proc. U. S. Nat. Mus. **37**: 369, 1909.
[4] Named in honor of my good wife, Margaret S. Westfall, whose help and encouragement are a great aid in my dragonfly work.

with rather long tawny hair projecting to rearward; the face, clothed with short black hair, is much less hairy than in *alleghaniensis*, the lateral surfaces of the frons being almost devoid of hair.

Thorax brown to blackish with metallic reflections, especially on the anterior surface; no trace of antehumeral light spots or stripes (except in one paratype where there is a small stripe about 1.75 mm. in height);[5] thorax clothed with brownish to light grey hairs, these being longest on the front of the thorax next to the anterior margin of the mesepisternum; yellow areas of antealar sinuses large and bright, slightly divided in the middle; a dull yellowish spot present at the junction of humeral suture with mesinfraepisternum; the metepisternal bright yellow stripe is rather broad, and of almost uniform width, passes over the spiracle and surrounds the thorax, being only slightly interrupted by the lateral crest and again at the wing base; latero-ventral metathoracic carina narrowly yellow; venter and synthorax yellow with a large triangular brown spot at rear, and a lateral stripe each side posterior to metathoracic leg bases. Legs dark brown to black, the posterior faces of pro- and mesocoxae pale yellowish; keel of first tibia about one-half length of tibia, that of middle tibia one-half to seven-twelfths the length of tibia, and that of hind tibia about five-sixths the length of tibia.

Wings hyaline, with only the faintest suggestion of brown at the base in the costal and subcostal spaces; extreme tips faintly tinged with brown; venation and stigma black, the costa only slightly yellow on its anterior surface; membranule whitish.

The abdomen narrows on segment 3 with little expansion to the end of segment 6; 7 expands more rapidly, and greatest breadth is reached at apex of segment 8, while 9 and 10 are only slightly narrower. Abdomen black, the following yellow: segment 2 with the usual band generally interrupted middorsally and narrowed but not interrupted at the level of the auricles; 3–6 with a pair of dorsal spots which are not confluent over the dorsum, decreasing slightly in size to rearward but always present, those on 4 about half or slightly less than half as long as the space between base of segment and transverse carina; 3 with the dorsal spot not joining the stripe on the basal inferior edge; 7 with a large basal spot which encircles the segment or is slightly interrupted laterally; 8 with a smaller spot dorsally not reaching the large spot on the basal inferior margin of that segment; 9 with a basal inferior spot, sometimes also with a distal inferior spot and a small lateral spot toward the apex; 10 with a small lateral spot. Hair of abdomen about half as long as in *illinoiensis*.

Caudal appendages viewed in profile: dorsal line of superiors almost straight, slightly elevated at the apex; inferior line almost parallel with the dorsal, not so noticeably constricted beyond base and widened near the apex as in *alleghaniensis*. Seen from above, there is a small mid-lateral tooth externally, which is not so sharp as in *illinoiensis* or *alleghaniensis*, but more robust. The inferior projects beyond the tips of superiors farther in *illinoiensis* than in this species.

[5] This specimen seems to be slightly aberrant in several respects in that it has four cubito-anal crossveins in one hind wing, and the oblique vein of one front wing appears branched.

The basal internal tubercle on the superiors when seen from a dorsal or dorso-lateral view is much larger in this species than in *alleghaniensis* or *illinoiensis*.

The genital lobes are black and much longer than in related species; posterior hamules are broad and stout, with a short comparatively broad tip which is black, becoming paler basally.

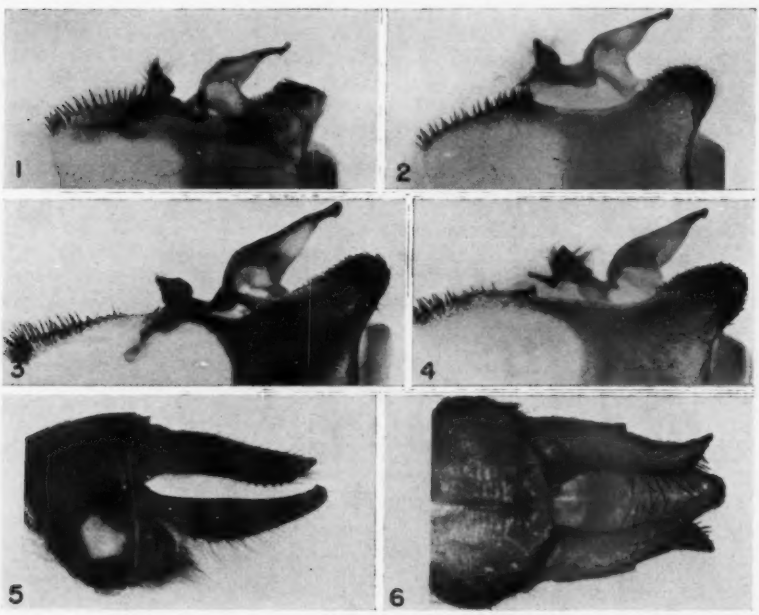
Female: in form, similar to the male, but larger and more robust, and with none of the tibiae keeled. The yellow spots of the frons are larger; the band on 2 is interrupted latero-ventrally as well as dorsally; dorsal spots on 3 to 6 larger than in the male; basal inferior spot on 3 almost absent; yellow of 7 reduced to a large basal spot; 8 with a much smaller dorsal spot; 8 and 9 with small basal inferior spots, but 10 all black. Anal appendages about as long as segment 10 and tapering to acute tips. Vulvar lamina extending about one-fourth the length of segment 9, rather deeply emarginated by a square notch in the middle.

Williamson (1909) listed in the form of tables extensive venational characters for the males of the species treated. I have recorded some of these characters for the ten specimens (9 ♂, 1 ♀) of *M. margarita*, and give the results here so that anyone may make a ready comparison with Williamson's figures. The numbers in parentheses indicate the number of wings with the corresponding character. Antenodals, fore wings, ♂ 15 (4), 16 (7), 17 (4), 18 (2), 19 (1), ♀ 19 (2), hind wings, ♂ 10 (4), 11 (11), 12 (2), 14 (1), ♀ 13 (2); postnodals, fore wings, ♂ 9 (1), 10 (7), 11 (6), 12 (4), ♀ 10 (1), 11 (1), hind wings, ♂ 11 (1), 12 (7), 13 (6), 14 (4), ♀ 12 (2); average distance nodus to stigma in length of wing, fore wing ♂ .304, ♀ .287, hind wing ♂ .378, ♀ .356. Triangles of front wings free ♂ (2), crossed ♂ (16), ♀ (2), hind wings free ♂ (9), crossed ♂ (9), ♀ (2); subtriangles of front wings free ♂ (10), ♀ (1), crossed ♂ (8), ♀ (1); antesubtrigonal cells in front wings ♂ 2 (5), 3 (13), ♀ 3 (2); cubito-anal crossvein in front wings ♂ 4 (8), 5 (6), 6 (4), ♀ 5 (2), hind wing ♂ 3 (17), 4 (1), ♀ 3 (2); first cubito-anal crossvein in hind wings midway between A_3 and A_2 ♂ (1), proximal to A_2 ♂ (12), ♀ (2), opposite A_2 ♂ (4), distal to A_2 ♂ (1); supratriangular crossveins in front wings ♂ 2 (9), 3 (8), 4 (1), ♀ 3 (2), hind wings ♂ 1 (15), 2 (3), ♀ 2 (2); crossveins over bridge in front wings ♂ 2 (8), 3 (8), 4 (2), ♀ 3 (1), 4 (1), hind wings ♂ 2 (5), 3 (12), 4 (1), ♀ 3 (2); no uncrossed posttrigonal cells in front wings ♂ and ♀; uncrossed postrigonal cells in hind wings ♂ 1 (1 partly crossed), 2 (10), 3 (6), 4 (1 with 4th partly crossed) ♀ 0 (1), 2 (1); arculus in front wings midway between 1st and 2nd antenodal ♂ (1), proximal to 2nd antenodal ♂ (14), ♀ (2), opposite 2nd antenodal ♂ (3), hind wings proximal to 2nd antenodal ♂ (13), ♀ (2), opposite 2nd antenodal ♂ (5); arculus in front wing proximal to 2nd cubito-anal crossvein ♂ (12), opposite 2nd cubito-anal crossvein ♂ (2), ♀ (2), distal to 2nd cubito-anal crossvein ♂ (4), hind wing proximal to 2nd cubito-anal crossvein ♂ (2 only slightly proximal), opposite 2nd cubito-anal crossvein ♂ (6), distal to 2nd cubito-anal crossvein ♂ (10), ♀ (2).

This species is separated from *illinoiensis* by the longer tibiae, the yellow ring on 2 of the male not interrupted at auricles and the much stouter posterior hamules and other venational differences. From *alleghaniensis* it is distinguished by the longer keels of the middle tibiae in the males, stouter posterior hamules with

short tips, male superior appendages and venational characters. From *georgina*, it is distinct by the absence of antehumeral stripes, stouter posterior hamules with short tips, longer keels on the middle tibiae, yellow inferior spots on segments 7 to 9, and several venational characters. Various characters for all of the species will be shown in tabular form in the forthcoming manual of the Odonata of North America.

The figures of the hamules and genital lobes of the four species here compared



FIGS. 1–4.—Lateral views of second abdominal segment of male showing hamules, genital lobe and edge of genital pocket. (All photographed to same scale.) FIG. 1.—*Macromia georgina* Selys. FIG. 2.—*Macromia illinoiensis* Walsh. FIG. 3.—*Macromia margarita* new species. FIG. 4.—*Macromia alleghaniensis* Williamson.

FIGS. 5 AND 6.—*Macromia margarita* new species. Lateral and dorsal views of tenth abdominal segment and appendages of male.

show the differences in size and shape of the hamules, the size of the anterior lobe, and the shape of the edge of the genital pocket. They are all reproduced to the same scale.

Holotype (male) and allotype (female).—Little River near Brevard, N.C., June 20, 1941; both in Cornell University collection (allotype ♀ was not taken in copulation).

Paratypes.—8 males from same locality and date as the holotype and allotype (one dissected in alcohol, others dry). Some of these will remain in the writer's

collection; others will be distributed to various collections where they may be seen.

A suggested change in the key by Walker to include this species is the following:

3— Fore tibia 7 mm.; hind tibia 11 mm.; latero-ventral metathoracic carina brown; yellow ring on abdominal segment 2 interrupted laterally (♂) or latero-ventrally (♀); yellow area of segment 7 in ♂ interrupted ventro-laterally....*illinoiensis*
Fore tibia about 9 mm.; hind tibia 13–14 mm.; latero-ventral metathoracic carina narrowly yellow posteriorly; yellow ring on abdominal segment 2 not interrupted laterally or latero-ventrally in ♂; yellow area of segment 7 in ♂ often encircling the segment.....3A

3A—Mesotibial keel of ♂ one-seventh to one-fifth as long as tibia; triangles of front wings free; antesubtrigonal cells of front wings 2.....*alleghaniensis*
Mesotibial keel of ♂ about one-half to seven-twelfths as long as the tibia; triangles of front wings usually crossed; antesubtrigonal cells of front wing usually 3.*margarita*

A DOUBLY MOSAIC DROSOPHILA OF UNUSUAL TYPE

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Mosaic individuals are those having spots of tissue which are genetically different from the rest of the organism. They therefore represent instances where there has been an irregularity of mitosis or of fertilization, or even of both processes in the same individual. Mosaics have been encountered frequently in well-studied species of animals and plants (Jones, '37; Stern, '36). Alteration or loss in an autosome would produce an ordinary mosaic, but such a change in a sex chromosome would result in a special type of mosaic, the sex-mosaic or gynandromorph, in which some tissues are male and others female. Gynandromorphs have received much special attention (Morgan and Bridges, '19; Bridges, '25; Patterson and Stone, '38). The present writer has encountered both gynandromorphs and mosaics a moderate number of times in working with *Drosophila melanogaster* and has reported some of them (Whittinghill, '38). The specimen here described seems to be sufficiently unusual to merit this special account.

This single fruit fly was not only a gynandromorph but also a mosaic for an autosomally determined eye color affecting spots of tissue in both eyes. The head was entirely female, but the thorax and abdomen were female only on the left side, whereas the right side was male. The body axis was curved toward the male side, which was smaller just as male Drosophila generally are smaller than females. Other evidences that the left side was female were narrower pigmentation bands on the abdomen, female genitalia, longer wing, and no sex comb on the left prothoracic leg. Correspondingly the right side of the body had the sex comb, shorter wing, right clasper and pigmented abdomen of males. The division line down the middle of the dorsal side of the abdomen was clearly marked. As described so far this specimen is not unlike a great number of other gynandromorphs already in the literature.

In addition to the bilateral division for sex, the eyes were mosaically colored. In the left eye there were three small sectors of over a dozen facets each, located dorsally, anteriorly and ventrally, which were colorless; and in the right eye a large white sector occupied the anterior quarter or third of that eye. All sectors went to the rim of the eye and none were in a posterior position, which facts are in accord with the observations of Sturtevant ('27) on mosaics involving the mutant Bar. The white color was not the sex-linked white. Rather it was due to the autosomal recessive brown acting jointly with vermilion. The phenotypically white spots were easily seen in the eyes, which were otherwise orange due to interaction of the genes vermilion and purple. The large colorless area in the right eye had a sharp ventral boundary and a diffuse posterodorsal border which appeared like a periclinal plane of separation between the two kinds of tissue.

Thus this single fly was mosaic for five spots, four of which were colorless sectors in the two eyes and the fifth was the male half of the thorax-abdomen.

KIN OF THE MULTIPLE MOSAIC

This was the only mosaic found in the course of two years of work with this particular stock of a new mutant wing shape character which the writer found in a vermilion brown stock in the summer of 1944. Phenotypically this vermilion brown combination is almost white and is here referred to as "colorless" to distinguish it from the effects of the sex-linked white gene, *w*. By outcrosses of the vermilion brown mutant wing stock to a stock containing the second chromosome

TABLE I

Parents and Sibs of the Double Mosaic

Parents: "colorless" female by "orange" male

$\frac{v \;\; Pr \;\; bw}{v \;\; pr \;\; bw}$ $\frac{v \;\; pr \;\; Bw}{Y \;\; pr \;\; bw}$

EGG TYPES	SPERM TYPES			
	v pr bw	*v pr Bw*	*Y pr bw*	*Y pr Bw*
v pr bw	$\frac{v \;\; pr \;\; bw}{v \;\; pr \;\; bw}$	$\frac{v \;\; pr \;\; Bw}{v \;\; pr \;\; bw}$	$\frac{Y \;\; pr \;\; bw}{v \;\; pr \;\; bw}$	$\frac{Y \;\; pr \;\; Bw}{v \;\; pr \;\; bw}$
	colorless	orange *	colorless	orange
	females		males	
	colorless	vermilion	colorless	vermilion
v Pr bw	$\frac{v \;\; pr \;\; bw}{v \;\; Pr \;\; bw}$	$\frac{v \;\; pr \;\; Bw}{v \;\; Pr \;\; bw}$	$\frac{Y \;\; pr \;\; bw}{v \;\; Pr \;\; bw}$	$\frac{Y \;\; pr \;\; Bw}{v \;\; Pr \;\; bw}$

Ratio expected	2 colorless	1 orange	1 vermilion
Offspring obtained	106	49 (50)	55

Legend:

* the probable starting genotype of the mosaic zygote
Y the Y chromosome normally present in males
v the recessive vermilion gene carried in an X chromosome
pr the recessive purple gene carried in the second chromosome
Pr the dominant, wild type allel of the *pr* gene
bw the recessive brown gene carried in the second chromosome
Bw the dominant, wild type allel of the *bw* gene

recessive purple, *pr*, offspring could be obtained which were orange in eye color due to the interaction of vermilion and purple in the presence of the normal allel of brown. The mosaic specimen was found as one of 211 offspring from a mating of a "colorless" female by 6 orange male sons as shown in Table I. It was preserved the same day it was found. This mating, a backcross, was made to test the genotype of the "colorless" female because she had a very dilute brownish color in her eyes. Under some culture conditions vermilion brown flies do develop this much color. Her offspring gave a testcross ratio thus showing that she was genetically vermilion brown, which is usually colorless. A computation of the chi square value for the distribution shown in Table I confirms the

very apparent good fit to the ratio expected. Hence the genotype of the orange parts of the mosaic must be vermilion purple and heterozygous for brown, *vv, pp Bwbw*, and the white parts must be tissues in which the recessive brown is able to act. There are several ways in which the latter would be possible.

DISCUSSION

Explanation of this combined mosaic and gynandromorph has two aspects, the qualitative changes which occurred and the place or places where they happened. The character of the changes will be easier to discuss first. The gynandromorphic aspect of the specimen is interesting but not unusual. Hundreds of them have been described (Morgan and Bridges, Patterson and Stone), and this writer has found them in other experiments previous to the present one and since. The bilateral division of the tissues is a very common arrangement among gynandromorphs, and it has been considered a direct consequence of the loss of one of the X chromosomes at the first zygotic or early nuclear division. A specimen which had started out as a female would become male in the tissues descended from that segmentation nucleus which received only one X chromosome. Such a loss would not affect the color of the eyes in this specimen.

The formation of colorless tissue in an orange eye could have been achieved in any one of five ways. First, the recessive brown might have become homozygous by mutation of the wild allel. Although the brown locus has been known to mutate to a recessive form well over 41 times in some thirty years of Drosophila breeding, mutation is less likely than either of two other changes below. Secondly, one might suppose, by analogy with the method of gynandromorph formation through the loss of a whole sex-chromosome, that the entire second chromosome containing the normal allel of brown had been lost here. This would allow the recessive brown to act in single dose. However, the second chromosome of *Drosophila melanogaster* is longer than the X chromosome, and it contains a very large number of the loci of the whole genome, and no example of the survival of a fly with the loss of this entire chromosome is known. Instead, thirdly, one might better suppose that only a part of the chromosome carrying the normal allel of brown had been lost. Small deficiencies are less likely to be lethal to the fly than are large ones, and many such deficiencies are known (Bridges and Brehme, '44). Many deficiencies for short sections of chromosomes are produced by irradiation, and some of them are spontaneous in untreated material. A deficiency opposite the recessive brown is a good possible explanation of a mosaic area, although it is perhaps not the best. Fourthly, another type of chromosomal change, inversion or translocation, with a break close to the locus of non-brown might allow the recessive allel to produce a phenotypic effect, since such a position effect has been described for the brown locus (Whittinghill, '42). Fifth and finally, somatic crossing over and segregation could produce a line of cells with the recessive brown homozygous. Crossing over outside of the maturation divisions has been demonstrated for somatic tissues (Stern, '36) and for the early germ line (Whittinghill, '37). Both authors have shown that it is higher in some lines and in certain crosses than in others. This crossing over in mitoses

seems to be possible because of the close somatic pairing of chromosomes which is characteristic of the Diptera. The hypothesis of crossing over seems a little more likely a method of releasing the brown gene from dominance than any of the other forms of change, because the necessary end result could be brought about by a chiasma forming anywhere between the spindle attachment and the brown locus, a map distance of 49.5 crossover units. By contrast a deficiency would have to be small and yet around the brown locus, and a position effect break would have to be very close indeed to the normal allel of brown.

Still another explanation for the quality of the two kinds of spots may be made. Double fertilization of a binucleate egg could have produced this unusual specimen, and such an hypothesis has seemed necessary in other instances. Both nuclei of the egg would have been *v, pr bw*. One fertilized by a *v, pr Bw* sperm would have given rise to tissue which was female and orange, the other fertilized by a Y, *pr bw* sperm would have given rise to male tissue without eye pigment. Irregular distribution of cleaving nuclei would then be required. However, no distinctively male tissue on the head adjoining the colorless eye sectors has been recognized on this specimen, as would be expected under this hypothesis.

If the diverse kinds of tissue in the mosaic and gynandromorph resulted in part from the loss of a whole X chromosome and in part from somatic segregation of the recessive brown, an explanation of the four separate spots of genetically brown tissue remains to be made. A separate occurrence of crossing over, or of deficiency formation, in four separate cells destined to form different parts of the eyes would explain the resulting phenotype although in a remotely probable way. Because one of the colorless eye sectors was many times larger than each of the other three it seems very unlikely that some external agent might have caused four simultaneous occurrences of this rare event, and no other orange or vermilion eyed sibs of this specimen had any such mosaic spots. Although the white areas were pie-shaped sectors suggesting a regular manner of cell production in late development, earlier some cell migration may have taken place. To see how often embryonic tissues appear to migrate, a search of the literature was made. A few examples approaching this in complexity were found, out of hundreds of mosaics described or pictured.

Evidence as to tissue migration during development may be found by returning to the studies of sex-mosaics of Morgan and Bridges (l. c.). Most of their 47 gynandromorphs have simple explanations. Those male on one side and female on the other, or those male anteriorly and female posteriorly or vice versa, can easily have been due to the loss of one X chromosome at the first division of a prospective female zygotic nucleus. Descendants of the aneuploid nucleus would be of the male phenotype. That the plane of the division between the two kinds of tissue is not always median sagittal but may be transverse shows that the first cleavage of *Drosophila melanogaster* is indeterminate. From other gynandromorphs which had a smaller amount of male tissue it has been concluded that the X chromosome may be lost at a later cleavage division. In some few specimens the two kinds of tissue seem to have dovetailed to some extent leading to a con-

clusion of Morgan and Bridges that "The segmentation nuclei descended from this same pair of cleavage cells were distributed in a regular but complex pattern." More extreme than this were three of the 56 mosaics described, for in these three some of the genetically identical tissues were discontinuously located. One (p. 48) was mainly male, on abdomen and thorax, but with female head and female external genitalia. Another (p. 54 and Pl. 4) was mainly female but with a male head and left thorax and with more male tissue on the end of the abdomen, right half only. In this specimen a bent body indicated the possibility of the smaller male tissue continuing internally beside female tissue. The third specimen (p. 57 and Pl. 4) was of the "quartered" type, in that the left anterior and right posterior quarters of the adult were male, leaving the opposite sectors, right anterior and left posterior, female. In addition there was an isolated spot of female tissue in an otherwise male eye. Thus 3 of Morgan and Bridges's 56 specimens had discontinuous spots, indicating some tissue migration.

Other examples have been described by Crew and Lamy ('38). Their 45 sex mosaics include five examples of flies with two or more spots of one kind of tissue surrounded by that of the opposite sex, i.e., numbers 7, 23, 36, 38, 40. In addition there were five other specimens which had spots in both eyes, with perhaps a connection between them internally, i.e., numbers 10, 14, 16, 27, and 32, which last is figured as 0.

Double and multiple spots were found by Patterson and Stone ('38) in ten per cent of 335 gynandromorphs. While 32 of these cases were two spot specimens, one (B, Fig. 70) was a three spot gynandromorph indicating a greater migration of segmentation nuclei.

Bridges ('25) reported a high frequency of piebald formation in 332 flies containing the M-n mutant, which enhances somatic crossing over and chromosome "elimination." About one-third of all flies inspected, or 105, were piebald: 68 of them had a single spot each, 28 had two spots, 7 had three spots and 2 flies each had four separate islands of the same kind of tissue. These last two represent as extreme cases of tissue migration as are known to the present writer.

Our specimen thus belongs among the distinctly unusual ones, since it has four spots of genetically brown tissue in a non-brown fly and since it is furthermore a bilateral sex-mosaic through thorax and abdomen. Evidently in this specimen there was much tissue migration in the future head region and practically none in the thorax and abdomen, because there the male and female tissues are separated by a straight line. To see whether segmentation nuclei might be less regularly distributed in the head than in the thorax the extensive data of Patterson and Stone's Tables 2–8 were resummarized. They had recorded mixed eye discs in 52 different specimens, wing discs of mixed composition in 27, mesonotal discs partly male and partly female 31 times, and 10 specimens in which one or both halves of the genitalia were not uniform. Insofar as ease of detection of mosaic spots on various areas is allowed for, their observations indicate that generally, even as in the present specimen, the eye discs are most often affected by abnormal distribution of growing tissue.

SUMMARY

A very unusual mosaic of *Drosophila melanogaster* is described. It was a bilateral mosaic for sex in thorax and abdomen and furthermore mosaic for an autosomal locus, this latter in four separate locations in the eyes. Comparisons with the more unusual specimens of other studies are made and the possible manner of origin is discussed.

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FURTHER NOTES ON CLAVARIAS, WITH SEVERAL NEW SPECIES

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Plates 1–14

During the twenty-four years since the publication of our book on the Clavarias, we have been trying to gain further information on that group. In the Journal of the Elisha Mitchell Scientific Society **42**: 251–254, 1927, and **55**: 382–386, 1939, we published some of the results of our observations, including descriptions of a few new species. In the present paper we are describing several other new species and assembling such additional notes and illustrations as will lead, in our opinion, to a better understanding of a number of species.

Clavaria rufobrunnea n. sp.

Plate 13, figs. 1, 2

Clubs simple, cespitose, 3–5 cm. long, 2–4 mm. thick, terete, natal brown (Ridg.), bases paler; stalk hardly distinct; odor none, taste not distinctive.

Dried plants dark brown to nearly black; base buffy brown, in largest ones for as much as 1 cm., but fading into club and not distinct. Club flattened by collapse, wrinkled and crooked and not regaining form when wet again but swelling somewhat and becoming less wrinkled; a soaked section showing the center now largely hollow with strands and plates of tissue traversing it.

Spores (of No. 9403) hyaline, oval, smooth, 3–3.6 x 3.8–5μ. Hymenium very dark, about 70μ thick, not splitting away from the compact paler flesh below, which is about 300–400μ thick before the larger cavities of the loose interior begin to appear; no cystidia present. Basidia about 7.5–8μ thick, 4-spored, projecting only slightly but easily found in our sections. Threads of the flesh very delicate, not much interwoven.

Growing on earth under conifers.

This species differs from *fumosa* in being smaller, much less densely cespitose, much darker both when fresh and when dry, and in somewhat shorter spores. *Clavaria nebulosoides* (see p. 56), a small wood-brown plant from Oregon, is even smaller, not cespitose, has cystidia and longer spores, and grows in mosses. It was sent to us by Dr. Alexander H. Smith of the University of Michigan, and the description is a combination of his notes on the fresh condition and ours on the dried plants.

California. Orick. A. H. Smith, No. 9403 (type). Under conifers, mostly redwoods, Dec. 4, 1937. Smith, No. 9467. Under conifers along trail, Dec. 6, 1937.

Clavaria cretacea n. sp.

Plate 1 (below) and pl. 12, figs. 7–10

Plants nearly simple, the few branches with open angles and upright or knob-like and spreading like an antler, tips thick and blunt; height 6.5–8 cm., about 4.5–7 mm. broad at broadest point, chalky white throughout with a faint tint of straw, tapering downward to a sharp point but with no distinct stem, flattened and grooved; flesh chalky white, brittle but of dry fibrous texture and easily splitting, becoming more or less hollow through separation of the fibers; no taste or odor.

Spores (of No. 13045) pure white on a good print, smooth, elongated, convex on one side and flattened on the other, 3–3.7(4) x 5.5–7.4μ, usually thickest toward the mucro; basidia 4-spored, 5–6μ thick, delicate and easily collapsing; hymenium about 33–40μ thick, with numerous inflated, hyaline, often irregular cells, or cystidia, up to 14μ thick, completely imbedded or extending to the surface; flesh composed of a denser, darker layer about 22–25μ thick next the hymenium, enclosing a looser, paler tissue in center; threads variable in thickness, mostly 3–7μ, branched and with cross walls; no clamp connections seen.

Except for collapse of the sides, dried plants do not shrink greatly and are a dull buffy brown, about Isabella color (Ridg.), the sterile lower part for 1.5–2 cm. becoming darker and more obvious. When dried plants are placed in water they do not revive at all.

The name refers to the chalky appearance of the fresh plants.

From stout forms of *C. falcata* this species differs in the much more delicate flesh which when dried collapses and is semi-hollow, while in *falcata* the flesh remains solid and white and is conspicuously duplex. The spores and hymenium are also quite different.

From *C. vermiculata*, another small, white, nearly simple plant, this species differs in larger size, single growth (not at all cespitose), chalk white surface and flesh, more fibrous texture, more sharply pointed base, somewhat larger spores, and in the peculiar hymenium.

North Carolina. Highlands. No. 13045 (type). In mixed woods by trail up Bear Pen Mountain, Aug. 24, 1942.

Clavaria Raveneliana n. sp.

Plate 2 (below) and pl. 12, figs. 3, 4

Plants small, up to 3.7 cm. high and 2.3 cm. wide; branching three or four times into a dense cluster, the branches spreading abruptly from a little central root; main body flesh color, tips clear light yellow with several short, sharp prongs, very base white; flesh pink, very firm, snapping when bent about 45°; no taste or odor.

Spores (of No. 12971, print) light yellow or deep cream, very abundant, short-ellipsoid with a lateral mucro and one side usually flattened, faintly warted or some smooth, 4–5 x 7–9.3μ. Basidia 7.5μ thick, 4-spored. No cystidia present. The flesh in cross section made up of a firm outer layer and a central core of loose tissue; when dry the central core collapsing to form a distinct cavity throughout most of the plant body, a branchlet 2 mm. thick showing a cavity about 1 mm.

wide, one 1 mm. thick showing center lightly stuffed; threads of flesh thin-walled, occasionally branched and with cross walls, in central region very irregular, inflated in places into bladder-like cells, threads under the hymenium smaller and more closely packed.

In external form these little plants are remarkably like those shown by Doty (pl. 8) as *C. testaceoviridis* (Atk.) Doty, but his plants differ distinctly in tough texture, greenish tips, bitter taste and quite different spores. Doty says of his plants "hollow from far down in the stem out into the tips." Our plants are not hollow when fresh but become so when dried. Dr. Doty kindly sent us some of his plants for direct comparison. His dried plants are darker than ours and the sides are so much collapsed as to appear flattish and with almost no cavity left at any point. The flesh is also much harder and tougher than in ours. Our spore measurements from a bit of the type of *C. testaceoflava* var. *testaceoviridis* Atk. are 3.8–4.8(5.2) x 10–12(13)μ, much longer and considerably rougher than in our species. Doty's figures for his plant are 3.2–3.8 x 9–11μ.

We take pleasure in naming this species for the late Mr. Samuel Prioleau Ravenel, who maintained a life-long interest in the Highlands region and in the preservation of its natural beauty and resources.

North Carolina. Highlands. Near the border of Lake Ravenel. No. 12971 (type). In an ample colony on bare earth by roadside under a hemlock with rhododendron near it, Aug. 16, 1942. No. 13035. Colony about five feet away from the one noted above, Aug. 24, 1942. Spores suboval, mucro face more flat, some faintly warted, 4–4.8 x 6.8–8.5μ, the mucro strongly oblique in some cases.

Clavaria subfennica n. sp.

Plate 11 (above) and pl. 12, figs. 5, 6

Plants upright, fastigiate, 12.5–17 cm. high, including the 3.5–6.5 cm.-long root, branched at the ground into 5 or 6 branches of uneven size, smooth or rugose-wrinkled, rebranched 4 or 5 times to end in rather long sharp slender concolorous tips, angles open; color of root white (not pink), then sordid when handled, exposed part(hymenial surface) deep dull brown (argus brown of Ridg.). Flesh soft, straw color, rather flexible, cracking at 45-degree bend; taste flat, odor none.

Spores (of No. 12879) chrome yellow in a good print (light orange yellow of Ridgway), minutely warted, 3.8–4.5 x 8.5–11μ. Basidia (of No. 13378) 4-spored, about 7–10μ thick. Hymenium about 33–41μ thick, very dark, with many spores imbedded in the outer two-thirds.

This plant in habit and dark brownish color resembles *C. longicaulis* but differs from that species and all other members of the *grandis* group in the entirely different spores. The spores are just like those of *C. fennica*. The color of the mature hymenium in the fresh state approaches that of *fennica*, but in the dried condition differs from it in its gray-brown instead of warm red-brown color. We have not found young stages of the present species but the fresh condition of the mature plant shows no traces of lavender color at any point, not even in the stem which in its slender, deeply penetrating habit is also very different from *fennica* with its blunt, swollen, shallowly rooted base.

North Carolina. Highlands. No. 12879 (type). In humus in deciduous woods on Fodderstack Mt., July 28, 1942. No. 13378. Near same spot as above, Aug. 3, 1943.

Clavaria appalachiensis Coker. Clav., p. 53, pl. 10 and pl. 91, figs. 13, 14. 1923.

Plate 4

Since our treatment of this species in 1923 (p. 53) we have collected it at Highlands, N. C., and have received several fine examples with photographs from Dr. L. O. Overholts from Pennsylvania and Canada. These more recent collections from both north and south, while usually irregularly compressed and furrowed, do not show the very regular and delicate longitudinal ridges emphasized in the types. While this condition must not be ignored we cannot find any other difference of importance and, as without this character the species is a well marked one, we amend the description to include these variations, as follows:

Plants simple, single or rarely cespitose in groups of 2-4, gregarious in small numbers; height 3-9 (12) cm., the stem distinct, 1-4 cm. long, terete, smooth and shining, pale lemon yellow except for the whitened and subtomentose base, tough and pliable, not breaking when bent on self, with a cartilaginous rind and a softer center; club 1.5-5 mm. thick, straight or bent, simple or not rarely once forked, equal and terete or more often compressed or channelled, at times delicately but very distinctly and regularly ridged and furrowed longitudinally (as in the type); color of club varying from pale fleshy buff or vinaceous buff to light salmon or creamy yellow, the rounded tips concolorous, then fading brownish; flesh of the club concolorous, very tender and brittle, snapping clean at an angle of 45°, solid but usually soon hollowed by grubs; taste and odor none; *spores* white, smooth, subspherical, 5-6.5 x 5.5-7.4μ, with a large oil drop and a small mucro; basidia 4-spored or (a few) 2-spored, 7.3-8.5μ thick; threads of flesh parallel, about 4.8μ thick under the hymenium, larger toward the center, where they are about 14μ thick on the average.

On beginning to dry the plants become rapidly much more white (noted by both Dr. Overholts and the author).

North Carolina. Blowing Rock. Nos. 5650, 5788, 5830, 5861.
Highlands. No. 13330. On damp bank under hemlock and rhododendron, July 26, 1943. Spores white, spherical, 6.6-7.4μ thick. No. 13389. In damp rhododendron-hemlock woods, Aug. 6, 1943. Spores 5.5-7.4μ thick.
Pennsylvania. Buck Hill Falls. Mrs. Delafield, coll.
Huntington County. July 21, 1942. Overholts, coll. Spores 6-8 x 7-8.5μ. Also No. 21227. On humus in forest, July 24, 1938. Spores 5.8-6.8 x 6-7.5μ. Overholts, coll.
Michigan. Isle Royale. In a cedar swamp, Sept. 6, 1930. A. H. Povah, coll. (Herb. Univ. Mich. No. P675).
Canada. Quebec. Overholts, coll.

Clavaria biformis Atk. Ann. Myc. **6**: 56. 1908.

Plate 5 (above)

Since our notes on *C. biformis* in 1939 (Journ. E. M. Sci. Soc. **55**: 385, pl. 44, figs. 15, 16) we have found it a number of times at Highlands. As the plant

body has never been illustrated except by our drawings (fig. 16) we are publishing herewith photographs showing different forms and sizes. In some of the forms the species is very like *C. Pogonati* (l.c., pl. 41), but that easily differs in large spores and association with moss protonema. A revised description follows.

Plants single or very sparingly cespitose, often in extensive colonies, varying from quite simple to several times dichotomously forked, rarely irregularly branched, at times from the base, forks open, growth distinctly crooked, very few of the plants being strict, very slender throughout, about $\frac{1}{3}$ to $\frac{2}{3}$ mm. thick, terete or often compressed in upper part; no clearly distinct stem; color dull white or pale cream or light buff except the paler tips; texture very elastic, not breaking when bent on self; odor none.

Spores (of No. 10567) pure white, subspherical, smooth, 2.5–3.4 x 3.2–4μ. Basidia (of No. 10534) 4-spored, about 4.8–6.5μ thick and 26μ long.

When dry the entire plant is brown, except tips usually paler. The compressed habit of the plant is a distinct character.

North Carolina. Blowing Rock. Atkinson.
Highlands. No. 9501. On rotten deciduous duff and humus, Aug. 13, 1932. Spores 2.8–3.2 x 3.8–4.2μ. No. 10534. In leaf mold, Aug. 16, 1937. Spores 2.2–3 x 3.4–4(4.5)μ. No. 10567. In humus, mixed woods, Aug. 22, 1937. No. 12970. On rotting log on Kelsey Trail, Aug. 15, 1942. Spores minute, subspherical, 2.5–2.9 x 2.5–3.7μ. No. 12976. Same colony as just above, Aug. 16, 1942. No. 12977. On rotten wood by Kelsey Trail, Aug. 16, 1942. Spores 2.5–3.5 x 3.5–3.8μ. No. 13060. On rotten wood and leaves, Aug. 27, 1942. Spores pure white, subspherical, 2.5–2.9 x 3–3.7μ.
New York. Ithaca. Type. Atkinson.

Clavaria botrytis Pers. (Comm., p. 42, 1797) and **C. rufescens** Schaeff. (Fung. Bavar., pl. 288, 1770)

Regarding the confusion between *Clavaria botrytis* and *C. rufescens*, it is clear that we have here in America two plants which are quite distinct, as we have treated them in *The Clavarias of the United States and Canada*. We there discussed under *C. botrytis* (p. 111) the difficulties one meets with, and we are still of the same opinion as there expressed.

In a recent work, Donk (1933) follows Maire, Cotton and Wakefield, and Rea in referring to *C. botrytis* the plant with long, striate spores. He does not include any species as *C. rufescens*, and Cotton and Wakefield cite *rufescens* as a synonym of *botrytis*. It is too much to ask one to accept the fine figures of *botrytis* as given by Fries, Krombholz, Rolland, and Dufour as representing the plant with striate spores (our *rufescens*). Bresadola's plate 1083 (Icon. Myc.) as *C. botrytis* is (except for spores) exactly like our *botrytis* and is not our *rufescens*; and his plate 1084 as *rufescens* is certainly not our *botrytis*, although he says that it is. Aside from the spores, which separate them at once, the two species are very easily distinguished if not too old: *botrytis* by the bright rose-pink tips of the branches when very young and for some time thereafter, but which gradually fade to concolorous at maturity; *rufescens* by the concolorous (whitish) tips when very young which gradually become wine color (rosy vinaceous) and then darker

brownish red on fading. In freshly mature plants the tips are darkest (about vinaceous fawn or light russet vinaceous, Ridg.), the color diffusing downward and fading out entirely in the basal part.

As Donk, Cotton and Wakefield, and Rea all refer to *botrytis* as seldom, uncommon, or very rare, it seems probable that they have not had sufficient material at all the different stages of development.

Burt in referring to the *C. botrytis* of American exsiccatae (Ravenel, Ellis and Everhart, and Shear) as not having striate spores, and following Cotton and Wakefield, wonders if *C. botrytis* occurs in America. He does not seem to have known *botrytis* in the fresh state and does not mention *rufescens*.

Dr. A. H. Smith has sent us from Ann Arbor, Michigan, a plant of *C. rufescens* which agrees with ours in every respect. He notes the large, striate spores and the color of the tips, which he describes as pinkish vinaceous ("Etruscan red" gradually fading to near "hydrangea pink").

Clavaria cinereoides Atk. Ann. Myc. **7**: 367. 1909.

Plate 2 (above)

In addition to the specimens listed in our treatment of this species in 1923, we have examined a number of collections (see entries below) and are adding a few notes on the fresh condition. We also include a better photograph than that published in our book.

Plants branched from the base, 2–7 cm. high, (1.5)3.5–6 cm. broad, uniformly ivory white to pale ashy gray when fresh, base of branches remaining whitish in drying and usually scurfy, upper portion of plant (hymenium) becoming pale ochre or buff except the cartilage-like tips; branches dichotomous, slightly clavate, numerous or few, axils acute or rounded, tips usually bidentate with the teeth blunt or rather acute, soon becoming brown; plants somewhat tough.

Spores (of No. 5664) white, globose, smooth, 4.2–5.6μ, with a large oil drop. Basidia slender, 4-spored, 7 x 40–45μ.

Illustrations: Burt. Ann. Mo. Bot. Gard. **9**: pl. 8, fig. 61. 1922.
Coker. Clavarias of the United States and Canada, pl. 20, pl. 83, figs. 8–11. 1923.

North Carolina. Chapel Hill. Type and No. 8270.
Blowing Rock. No. 5664.
Linville Falls. No. 5751.
Alabama. R. P. Burke, coll.
New York. Chappaqua. No. 542. Mrs. Murrill.
Tripoli. No. 32 and No. 99. S. H. Burnham.
Vaughns. S. H. Burnham.
Massachusetts. West Roxbury. Miss Ann Hibbard.
Vermont. Newfane. Miss Hibbard.
California. Crescent City. Under redwood, Dec. 5, 1937. A. H. Smith, No. 9434. (Univ. Mich. and U. N. C. Herb.)
Orick. Under redwood, Dec. 6, 1937. A. H. Smith, No. 9458.
Sweden. Stockholm. Lars Romell.

Clavaria contorta Holmsk. Beata Ruris Otia **1**: 29. 1790.

C. brachiata Fr.
C. alnea Schulz.

Plate 5 (below)

In our Clavaria book we discussed the difficulties in regard to the *fistulosa* and *contorta* groups and came to the conclusion that the above group might be different from the *fistulosa* group (*fistulosa*, *Ardenia*, *macrorhiza*). Since then we have received plants from Pennsylvania (Dr. Overholts) and Canada (Dr. Jackson) which certainly represent *contorta*. Dr. Overholts sent a photograph with his plants which we are publishing herewith. They are little simple, club-like forms, not twisted nor contorted, about 5–15 mm. high and about 1.5–2.5 mm. thick. They are erumpent on corticated birch twigs resting on rhododendron branches and entirely free from the ground. Each plant is supported on a little white foot up to a mm. or two high. The spores are 7.4–8.5 x 12–16 μ. The plants from Ontario are small crumpled little bodies on corticated poplar, with spores 6.2–8 x 12.2–16 μ.

Going over the material mentioned in our book as *contorta* and the two collections mentioned above for spore measurements, we find them to average about 6.9–8.4 x 13.2–18 μ. These figures compare closely with those given by Harper (Mycologia **10**: 55. 1918) for his plants of *C. contorta*. The spores of *fistulosa* are supposed by Lind, Cotton and Wakefield, and others to be smaller than those of *contorta*. The spores of our collections of *fistulosa* average 5.4–6.5 x 12.5–14.5 μ, thus according with the above conclusion.

Other than on alder, *C. contorta* is reported, so far as we know, on corticated twigs of hazelnut, birch, poplar, elm, maple, oak, and *Prunus* (Boudier). It is often supposed that *C. fistulosa* grows only in coniferous woods, but Cotton and Wakefield say "on fallen branches lying amongst dead leaves"; Lind gives it only on beech; Donk says beech, oak, alder, chestnut, and seldom on coniferous humus. Donk considers *contorta* only a form of *fistulosa* and gives its occurrence as chiefly on alder.

Sections of a *contorta* plant from Pennsylvania shown in the plate gave the following microscopic details: hymenium about 60 μ thick; subhymenium of delicate interwoven fibers about 10 μ thick; compact tissue about 110 μ thick, not distinctly divided into zones but composed of large and small fibers mixed, with not much difference in the thickness of the walls, cross-walls plentiful, no clamp connections seen. Inside this tissue were irregular clumps of crumpled and disorganized material, the remnants of the collapsed tissue next to the large cavity.

A typical specimen of *fistulosa* from Ontario, Canada (Jackson, No. 3403) showed the following structure: hymenium 45 μ thick; subhymenium of delicate interwoven fibers 15 μ; a layer 60 μ thick, of small densely packed, thick-walled, parallel fibers; and a layer about 165 μ thick of mixed large and small, thin-

walled, parallel fibers with numerous cross-walls; no clamp connections seen. In these dried plants, although spores were plentiful, no sterigmata could be demonstrated on the long stout elements of the hymenium.

The distinctions between *contorta* and *fistulosa* are well expressed by Cotton and Wakefield, who say "The chief points of distinction in *C. contorta*, besides its dwarf, fasciculate habit, are its paler, more greyish colour, entirely smooth club, covered everywhere with the hymenium, its occurrence on dead branches still remaining on the tree, as well as on fallen ones, preference for *Alnus incana*, and larger spores." In addition to these differences, Lind (Ann. Mycol. **5**: 272. 1907) mentions also the erumpent habit instead of formation on top of the bark as in *fistulosa*. In this paper Lind is taking issue with Von Höhnel (Oest. Bot. Zeit. **54**: 425. 1904) who considers them forms of the same species. Bourdot and Galzin (Hymén. de France, p. 120) agree with Von Höhnel and give strong argument for their view. Their illustrations of numerous plants, said to be taken from the same group, are impressive, and they say that on branches with one end resting on the ground they have found on the same branch the *contorta* form above the ground and the *fistulosa* form at the end resting on the ground, but that the latter usually grows on debris more or less buried in humus. It must be noted however that they give the spore of the *contorta* form as somewhat larger than of their *fistulosa*.

Considering what has been said above, it seems to us that since *C. contorta* has long had a specific name it is just as well to treat the two forms under their separate names. If *contorta* is only a form of *fistulosa*, it is a remarkable example of striking differences due to habitat. The obvious way to settle this dispute would be to grow both forms in pure culture.

Clavaria cristata (Holmsk.) Pers. Comm., p. 43. 1797.

Plate 3

In further reference to the extreme variability of this species, we give herewith a photograph of a plant with some of its divisions typically cristate, others in the form of *rugosa*. The color of the plant was not white but pale ashy brown, changing to much darker where attacked by a parasite. The spores are subglobose, about 7.5μ thick.

Clavaria cystidiophora Kauff. Pap. Mich. Acad. Sci. Arts and Let. **8**: 147. 1927.

Plate 12, figs. 11–14

Through the kindness of Dr. A. H. Smith we have examined the type of this species. The plants are now small, the tallest only about 6 cm., now deep brown except upper part of one, as if dried after fading. Kauffman gives the spores as 3.5 x 5.5–7 μ, but our measurements of those of the types are 3.5–3.8 x 7–8(9.3) μ; cystidia as described, about 5.5 μ thick; basidia 4-spored, about 6.3 μ thick; organized hymenium about 55 μ thick; just underneath the hymenium a dense layer of parallel threads, then loose open tissue in the central region.

Since the publication of this species, we know of no record of its collection, but we have received from Dr. Smith some plants in good condition and with notes that we are considering *C. cystidiophora*. Dr. Smith's notes are as follows.

Fruiting body about 15 cm. high, originating in the ground as a mass of primary stems attached to a tubercle, the stems whitish and appressed together into a stemlike mass 7–8 cm. long, above ground branching 3–4 times, the angles rounded and the secondary branches more or less parallel, making a high narrow fructification, ultimate tips rather abruptly pointed (no cups at apex), lower portions of plant are yellow to white, tips and uppermost branches "pinard yellow," no color changes observed from bruising, the basal parts merely sordid avellaneous in age; odor and taste none or not distinctive (slight and fungoid).

Spores brown, 9 x 3μ.

Essentially a slender, much branched species which does not spread out and has bright yellow tips when young. In age upper portion of secondary branches is pale yellow and tips only slightly brighter.

The dried plants are now up to 12 cm. tall, and bright, buffy ochraceous in color; odor strong, variously described as of tobacco, cedar, or suggesting fenugreek to some. We find the spores to be ellipsoid, minutely warted or some nearly smooth, 3.5–4 x 9–11.2 μ (somewhat larger than in the type); basidia 4-spored, 6–7.5 μ thick; cystidia scattered but not rare, hyaline, thin-walled and readily collapsing, irregularly club-shaped, variously swollen in places, about 5.5–8.5 μ thick and extending up to 35–40 (rarely 48) μ and rather frequently with a cross wall about 22–26 μ from the end.

Illustration: Doty. Ore. St. Monog., Stud. in Bot. No. 7: p. 3, fig. 17. 1944.

Washington. Lake Quinault. In humus under conifers, Oct. 17, 1925. C. H. Kauffman (type).

Shuksan Inn, Mt. Baker area. Single under hemlock, Aug. 18, 1941. A. H. Smith, No. 16258.

Clavaria falcata Pers. Comm., p. 81 (213). 1797.

Plate 6 and pl. 14, figs. 1, 2

Since our treatment of *C. acuta* (1923, p. 25), described from plants collected from a conservatory pot in the New York Botanical Garden, and considered by us as possibly the same thing as *C. falcata* Pers., we have found (summer, 1942 and 1943) three lots of a plant at Highlands, North Carolina, that we have decided should be treated as the true *falcata* of Europe. Over a hundred years ago Schweinitz listed from North Carolina what he considered *C. falcata*, and it has since been reported from Alabama (Peters, coll.) by Saccardo and Mohr, but we consider the Alabama plants *C. filipes*.

As indicated in our book above mentioned, it is impossible from treatments of European authors to make out with clearness any important differences between *C. acuta* Sow. and *C. falcata* Pers. Both are small, white, simple, non-cespitose plants with distinct, pellucid stalks and large white spherical spores. Of *C. acuta* Cotton and Wakefield and also Donk give the basidia as 2–4-spored, while

Schroeter says they are 4-spored. Of *C. falcata* Patouillard gives them as 2-spored, Bourdot and Galzin as 2–4-spored. In our plants from the New York Botanical Garden, described by us as *C. acuta* (l.c., p. 25), as well as those of *C. falcata* from Highlands, the basidia, so far as observed, were 4-spored. It is possible that 2-spored basidia could be found with further search. It will be seen from the photographs that all our Highlands collections are falcate in large part, and we now have little doubt that they are really *falcata* as understood by Patouillard (Tab. Anal. Fung. No. 258). No European author has given a satisfactory description of *both* of these species and carefully compared them in the fresh condition. Only Schroeter includes them both as seen by him, but mentions the basidia and spores only of *acuta* and gives no important differences in his short description of *falcata*.

The conservatory plants of New York, described by us as *acuta*, when compared in the dry state with our Highlands plants, have a very different appearance. Both club and stalk of the former are just alike in having the red subtranslucent appearance of cartilage, the stalk differing only in being more slender, the whole shrinking to a mere filament not more than $\frac{1}{3}$ mm. in diameter. Fine examples of *C. acuta* from Dr. Cotton from a conservatory at Kew and from Wales (habitat not given) are essentially like ours, greatly shrunken and with the appearance of cartilage. On the other hand our Highlands plants are far less shrunken (larger clubs up to $2\frac{1}{2}$ mm. thick) with a dull buffy leather color, showing in section a distinct thin darker rind around a soft white central column, a very striking character. All of the Highlands plants when dry are thicker at or near the tips than elsewhere. Their falcate habit is also markedly different from the erect habit of the New York and the English ones. We therefore conclude that *acuta* and *falcata* are distinct and differ in the characters indicated.

Our description of *C. falcata* follows.

Single and separate but usually several in a scattered group, very variable in size even in the same group, 1–5 (7.5) cm. high, usually curved, blunt, clavate or the smaller ones nearly cylindrical, terete or more often pitted or compressed in places, about 1–3.5 (4.5) mm. thick above, milk white throughout; texture brittle, snapping clean on bending, solid but stuffed within a firmer rind; taste slight, a little mouldy, odor none.

Stalk about 1–2.5 (3) cm. long, distinct, concolorous but translucent and more slender and elastic than the club.

Spores (of No. 12864) pure white when fresh (becoming yellowish on a good spore print after drying in the herbarium), smooth, subspherical with a small mucro, 7.5–8.5 x 8.5–9.3 (10)μ. Basidia 4-spored, considerably enlarged toward the end, 7–9 x 25–30μ.

This differs from *C. acuta* as represented by our New York and English plants in the prevailingly curved habit, far less delicate structure, duplex flesh, which when drying shrinks only moderately, retaining its form and still more clearly showing its duplex structure. *Clavaria acuta* has often been found in conservatory pots, while we cannot find that *falcata* has been so reported.

In shape our plants of *falcata* are rather like *C. subfalcata* Atk., but the former are distinctly less delicate, the flesh is sharply duplex and they shrink less in

drying; they also differ in both color and spores. We also find that after a few months the spores of *falcata* turn from pure white to distinctly yellow, while those of *subfalcata* remain pure white. Quélet's var. *citrinopes* of *C. falcata* differs only in the yellow stem.

Illustrations: Micheli. Nov. Pl. Gen., pl. 87, fig. 5.
Patouillard. Tab. Fung., No. 258.
Persoon. Comm., pl. 1, fig. 3. 1797.

North Carolina. Highlands. No. 12864. On humus and gravel by path running under "Dry Falls," July 27, 1942. No. 13388. In humus in damp rhododendron-hemlock woods, Aug. 6, 1943. Spores 7.7–8.5 x 8.5–10μ. No. 13520. In wet soil on rocks under "Dry Falls," Aug. 22, 1943.
?Salem. Schweinitz(Curtis Herb.). "Non rara locis muscosis."

Clavaria globospora Kauff. Pap. Mich. Acad. Sci. Arts and Let. **8**: 148. 1927.

Plate 14, figs. 11, 12

The dried plants of the type of *C. globospora* in the University of Michigan Herbarium are now irregular, collapsed and flattened, but rather richly colored. The basidia were described as 2-spored but we find on the type plants as many 4-spored as 2-spored. The bases of the type were described as inserted and naked but the dried plants of the type and also of the three collections entered below show bases surrounded by a conspicuous soft white pad or boot. The color of the dried clubs is a bright ochraceous orange or darker ochraceous tawny, contrasting strongly with the white foot. (Our collections from Dr. Smith were accidentally overheated in getting out some insects and do not now show the bright colors above mentioned.) The plants are solid at first but may become cavernously hollow. They reach a size of 14 cm. tall and 5–7 mm. wide.

Spores (of type, our measurements) globose, smooth, 5.5–6.5(7) μ.

The species is very close to our *C. appalachiensis* and may be only a form of it. At most it seems to differ only in less distinct and less yellow stem, more strictly simple habit, and brighter color when dry.

Illustration: Doty. Ore. St. Monog., Stud. Bot. No. 7: pl. 2, fig. 3 (spores). 1944.

Washington. Lake Quinault. (Type) On very rotten wood of conifers, Oct. 28, 1925. C. H. Kauffman.
Mt. Angeles, Olympic Mts. On old wood, Sept. 26, 1941. A. H. Smith, No. 17319. "Cream color over all." Spores 6–7.4μ thick; basidia numerous, 4-spored or possibly some 2-spored (not clear), 6.5–7.2μ thick.
Oregon. Blue River. Under conifers, Oct. 17, 1937. A. H. Smith, No. 7902. Spores 5.5–7(7.4)μ; basidia (few seen) 4-spored.
California. Orick. On humus under redwoods, Dec. 6, 1937. A. H. Smith, No. 9473. "Head and stipe distinct, head 'Cadmium yellow,' stipe paler."

Clavaria Invalii Cotton and Wakefield. Trans. Brit. Myc. Soc. **6**: 176. 1919.

C. abietina Fr. (not Pers.)

C. flaccida subsp. *Invalii* Konrad and Maublanc. Icon. Sel. Fung., pl. 488.

Plate 11 (below)

In our Clavaria book (pp. 179–186) we treated under the name *Clavaria abietina* Pers. three separately described forms. One of these we called the "non-virescent form of pines." Donk (1933, p. 113) says that this form is the same as *C. Invalii*, which he transfers to the genus *Ramaria*. After further study of our collections and of the literature, we have come to the conclusion that he is correct, and we are now using the name *C. Invalii* for our plants. This species is larger, stouter, with more distinct stem than the true *abietina* Pers.; color when fresh yellowish cinnamon, not turning green in age or on bruising, drying ochraceous tawny above, the stem usually a little paler ochraceous buff, the base more or less enlarged, light buffy cream, not pure white as is conspicuously so in *abietina* Pers. Also the spores of *Invalii* are somewhat larger than in *abietina* Pers. Both Seth Lundell (Fungi Exs. Suecica, Fasc. 3–4, No. 140) and Donk agree that *C. abietina* Fr. (not Pers.) is the same as *C. Invalii*. For a good colored illustration of this species, see Gramberg, Pilze der Heimat II (3rd. ed.), pl. 33, 1921 (as *C. abietina* Fries).

Clavaria Kunzei Fr. Syst. Myc. **1**: 474, 1821; Hymen. Eur., p. 669, 1874.

Donk (p. 90) thinks that we have not seen fresh material of the true *C. Kunzei*. Our reasons for referring the plant, of which we have collected and studied excellent fresh material, to *Kunzei* are fully discussed in our treatment (1923). Our species is the same as interpreted by Cotton and Wakefield. The specimen of *chionea* in Persoon's herbarium is certainly the same as our plant and Fries considers this the same as *Kunzei*. As noted by me (p. 98–99), some of our collections included under *Kunzei* show variations that may or may not be of specific importance, but we see no reason to change the name of the North Carolina plant which we have described as *C. Kunzei*.

Donk refers to Quélet's figure of *Kunzei* (Champ. Jura et Vosges, pt. 3: pl. 2, fig. 11, 1875) as representing his plant but does not note that Quélet's description and figure of the spores is entirely incorrect for the species. We also noted that Quélet's figure looks like our plant, but did not enter it because of the discrepancy in the spores.

Clavaria luteo-alba Rea (Trans. Brit. Myc. Soc. **2**: 66, 1904) and **C. helveola** Pers. (Comm., p. 69, 1797; Myc. Eur. **1**: 180, 1822)

In our Clavaria book (p. 37) we used the name *C. helveola* for the plant common in the United States which is usually referred to *inaequalis* in American herbaria. We called attention to the fact that Cotton (Trans. Brit. Myc. Soc. **2**: 164. 1906) had cleared up the uncertainty about *inaequalis*, an entirely different species. Under *helveola* we listed as a probable synonym *C. luteo-alba*, but used the name *helveola* because of the close similarity of our plants to Per-

soon's description of *C. helveola*. We had examined the plants under that name in Persoon's herbarium but could find no spores other than mold spores on them.

Donk (p. 83) uses Rea's name *luteo-alba* for our plants and says he has determined without any doubt that the true *helveola* is the same as *inaequalis*. From this we infer that he has found good spores of *helveola* in Persoon's herbarium, which should settle the matter, and we are therefore accepting his decision and applying the name *luteo-alba* to our plant.

Clavaria luteo-alba form **montana** n. f.

Plate 7 and pl. 14, fig. 4

In 1923 (p. 40) we entered under *C. helveola* a collection (No. 5571) from Blowing Rock, N. C. These plants differed from the usual form in being shorter, less cespitose, of a deeper orange color, and in having proportionately thicker clubs and more distinct stalks. Since that time we have made six other collections at or near Highlands, N. C., all showing very short plants of a deep orange color and rather sparsely cespitose or single. All of these plants are certainly forms of the species *luteo-alba*, with yellow or orange flesh and the same spores, and a few of the Blowing Rock plants showed some greenish fibrils on the stem.

Spores (of No. 5571) subellipsoid, slightly inequilateral, with proximal end tapering, 3.5–3.7 x 6–7.6(8) μ. (Spore size as given in our book for *helveola* is too small,—should be 3–3.5(4) x 7–8.2 μ.) Basidia (of No. 12617) clavate, 2- or 4-spored.

In the meantime we have found at Highlands only one collection of *luteo-alba* of the usual form, and it appears that the prevalent mountain plants deserve a form name. We are publishing herewith three photographs which will help in recognizing it. The upper two show intermediate forms from Highlands.

North Carolina. Blowing Rock. No. 5571 (type of the form). In humus in woods, Aug. 19, 1922.

Highlands. Nos. 10610, 12617, 12645, 12706, 12709, 12710. Spores (of No. 12710) 3.7–4.2 x 7–9μ.

Clavaria maricola Kauffman. Pap. Mich. Acad. Sci. Arts and Let. **8**: 149. 1927.

Plate 13, figs. 3, 4

We have examined the type of this species from the Herbarium of the University of Michigan and also a large collection by Dr. A. H. Smith from the type locality which is undoubtedly the same thing. These seem to be the only collections so far known. We are publishing our drawings of the spores of both. We find the spores of the type to be 4.2–5.2 x 9.3–11.8(12.5) μ. If the spores are left in KOH solution for more than a few minutes they expand to an unnatural thickness.

Illustration: Doty. Ore. St. Monog., Stud. in Bot. No. 7: pl. 3, fig. 22. 1944.

Oregon. Takilma. On needles and cones of western yellow pine, Nov. 1925 (type). C. H. Kauffman, coll. Under *Pinus ponderosa*, Nov. 20, 1937. A. H. Smith, No. 8929. Spores rather regularly ellipsoid, smooth, 4.2–5.2 x 9.5–11.2μ.

Clavaria nebulosoides Kauff. Pap. Mich. Acad. Sci. Arts and Let. **5**: 118. 1925.

Plate 13, fig. 5

We have examined the type of *C. nebulosoides* from the herbarium of the University of Michigan and consider it a good species. The dried plants are very slender and only up to 2.5 cm. high, light ashy brown, the base puberulent, whitish and a little swollen. Spores hyaline, smooth, ellipsoid, 2.2–3.5 x (5.6) 6–7.4 μ (our measurements); cystidia present as described. The plants do not regain their shape when wet.

Illustration: Doty. Ore. St. Monog., Stud. in Bot. No. 7: pl. 2, fig. 13. 1944.

Oregon. Mt. Hood. On mosses in conifer forest. C. H. Kauffman.

Clavaria piperata Kauff. Pap. Mich. Acad. Sci. Arts and Let. **8**: 146. 1927.

Kauffman describes this species as differing from *C. pyxidata* "by the colored, differently shaped spores, its peppery taste, different color when fresh, and its coniferous substratum."

Through the kindness of Dr. A. H. Smith, we have seen Dr. Kauffman's types and in looking over our material and comparing it we can find no constant difference except a slight difference in the spore shape, his plants having spores slightly broader (3–3.5 x 3.7–4μ; ours (2.2)2.5–2.8(3) x 3.5–4.5μ), thus giving them a more oval outline. His types were from coniferous wood, while all our numerous collections of *pyxidata* were on deciduous wood. A number of ours were very peppery when collected and these certainly grew on deciduous wood. Kauffman suggests that my peppery ones with cystidia may have grown on coniferous wood, but this is not the case, as was plainly stated in our published notes. His including spore color as a difference seems to rest on a difference detected under the microscope. We have numerous spore prints, all pure white, and under the microscope we can detect no difference in the color of the spores of his and our plants. Rea (1922) says *pyxidata* occurs on rotten and buried wood; spores 4 x 3 μ, which is the same as Kauffman's plants. One of our collections (Vaughns, N. Y., Burnham No. 109) has spores 2.5–3 x 3.5–4 μ, almost as in Kauffman's but this also grew on deciduous wood. Wehmeyer (1935) reports *pyxidata* from Nova Scotia "on decayed logs," kind not noted; spores 2–2.5 x 3.3–4.5 μ, and "hyaline cystidia which project 16–20 μ beyond the hymenium"; peppery taste slight and developed slowly.

It seems from the above facts that Kauffman's species is best treated as a form or variety of *pyxidata*.

Clavaria pistillaris Linn. (Sp. Plant. **2**: 1182, 1753) and **Craterellus pistillaris** Fr. (Epicrisis, p. 534, 1836–38; Hymen. Eur., p. 632, 1874).

The long controversy as to whether *Clavaria pistillaris* Linn. and *Craterellus pistillaris* Fr. (= *Clav. truncata* Quél.) are the same species is still unsettled. Atkinson (1900), Bresadola (1932), Harper (1913), Juel (1916), Lloyd (1920)

and the writer (1923) have all considered them forms of the same thing. On the other hand, Burt (1914, 1922) and Konrad and Maublanc (pl. 495) treat them as distinct. Donk (1933) expresses doubt of their being the same, saying that Bresadola and the writer may have been too hasty in their conclusions. He says (trans.): "*Craterellus pistillaris* is a species with truncate, sometimes indeed an umbilicate end. The sides are more or less strongly wrinkled. The species is moreover, at least in Europe, confined to coniferous woods. The flesh tastes sweetish, never bitter as in *Clavaria pistillaris*." In his treatment of the latter species he gives the habitat as frondose woods. Fries himself, under *Craterellus pistillaris*, says "Around Upsala frequent in pine woods in which the true *Clavaria pistillaris* is never seen." (But see Lloyd, Myc. Notes, p. 988, who says a specimen of *Clavaria pistillaris* in Fries's herbarium from near Upsala does not bear this out.) Harper finds what he calls *Craterellus pistillaris* in coniferous woods but goes on to say that "Atkinson and others are undoubtedly right in considering Fries's plant [*Craterellus pistillaris*] a variety of *Clavaria pistillaris*, and it should be placed in a group with that species." [Atkinson really says form, not variety, as Harper correctly says on the preceding page.]

Burt mentions the bright colors (p. 342) shown in illustrations of *Clavaria pistillaris*, but he himself describes the species as whitish to dingy ochraceous, and moreover many illustrations of the truncate plant often show the most brilliant colors of all (e.g., Konrad and Maublanc, l.c., Krombholz, figs. 5 and 6, cited below) and Lovejoy (Bot. Gaz. **50**: 385, 1910) describes her plant as having "pileate tops bright red, shading into reddish orange at top of stipe to dull flesh color at its base." According to the records, therefore, the color does not in any way separate these forms. We note again, however, that the southern plant we are calling var. *unicolor* exhibits, with rare exceptions, only the subdued tints of brown or flesh.

To emphasize still further the difficulty of clear distinctions in this group, note the plant illustrated in our Clavaria book on plate 23 (as *Clavaria pistillaris*). It grew in Connecticut under hemlocks in cespitose clusters, was bright rosy pink when young, in part deformed in peculiar ways, and was bitterish in taste. Moreover the spores (good print) were smaller even than in any of our collections of *unicolor*. It fits nowhere comfortably. Another intermediate collection is Burnham No. 71, from Vaughns, New York, noted in our book. In size and shape it agrees with *unicolor* but its spores are very large, 5.5–7 x 9.3–12.5 μ. Such plants have been described as *Clavaria truncata* Lovejoy, which has similar shape and large spores, "7 x 14 μ".

A description of *Clavaria pistillaris* follows.

Plants very variable in size and shape, (6)10–15(20) cm. high, regularly clavate to obovate with rounded and nearly smooth tip or swollen and rugose to crumpled and up to 4–5(7) cm. thick above, at times splitting at the apex and forming a cavity into the hollow flesh; in forma *truncata* with tip broadly truncate and often collapsing into the hollow below; color extremely variable, usually palest when young, becoming buffy ochraceous to reddish brown, at times with a tint of chocolate, the blunt base white and more or less rooting; flesh white, solid below, soft and cottony and becoming hollow above, taste bitterish.

Spores pure white, smooth, subellipsoid, tapering proximally into a lateral apiculus, (5)5.5–7(7.4) x (8)9–13.5(15)μ (average of 14 collections, 5.3–6.7 x 9.5–12.1μ). Basidia long-clavate, 2-4-spored, about 10 x 70μ; hymenium covering the upper two-thirds or more of the plant, extending over the top in the rounded forms or with a sterile area of variable size on the top of the truncate clubs.

Growing singly or in small groups, often cespitose, in deciduous or mixed woods, less often under conifers, sometimes in moss or grass.

For illustrations of the truncate form see:
Bresadola. Icon. Myc. **23:** pl. 1102.
Burt. Ann. Mo. Bot. Gard. **1:** pl. 16, fig. 13; pl. 17, fig. 14. 1914.
Harper. Mycologia **5:** pl. 95. 1913. Good.
Konrad and Maublanc. Icon. Sel. Fung. **5:** pl. 495.
Krombholz. Abbild. u. Beschr., pl. 54, figs. 5, 6 (other forms also shown).
Lloyd. Myc. Notes, pl. 158, fig. 1755 (right).
McIlvaine. Amer. Fungi, pl. 138, fig. 2 (shows both forms).
Schaeffer. Fung. Bavar., pl. 169.

North Carolina. Chapel Hill. No. 14068. In mixed woods, Oct. 25, 1946. Spores 5–6(6.5) x 8–10(11)μ.
Blowing Rock. No. 5623. In deciduous woods mold, Aug. 20, 1922. Spores 6–7.2 x 10–13μ.
Haywood County. No. 8027. Spores subpyriform, 5.5–6.3 x 10–11μ.
Highlands. No. 12700. In mixed mountain woods, Aug. 25, 1941. Large plants, 5.5 cm. thick and 19.5 cm. tall. Spores 6.3–7.2 x 11–13.5μ. Also Nos. 9599, 12308, 12911, 13101 from Highlands.
Linville Falls. No. 5759. Under chestnuts, Aug. 24, 1922. Also No. 8354.
Pink Beds. No. 280. Miss Burlingham.
Tennessee. Grassy Patch. No. 10419. A. H. Smith, coll.
New York. Vaughns. Burnham, coll. Nos. 15, 68, 71 (intermediate form) and 139.
Connecticut. Redding. No. 27. Under hemlocks, Sept. 6, 1919 (intermediate).
Wisconsin. Blue Mounds. R. A. Harper, coll. No. 162.
Colorado. Tolland and Leal. Typical form and f. *truncata* reported by Kauffman (Pap. Mich. Acad. Sci. Arts and Let. **1:** 124. 1921).
Wyoming. Foxpark. Type of *C. truncata* Lovejoy.
Washington. Olympic Hot Springs. A. H. Smith, coll. No. 17144.
Oregon. Belknap Springs. A. H. Smith, coll. No. 8133.
Cave Junction. Under oak and pine, Nov. 29, 1937. A. H. Smith, No. 9181.
Oregon Caves road. A. H. Smith, No. 9323.
Frog Lake, Cascade Mts. A. H. Smith, No. 19092.

Clavaria pistillaris var. **unicolor** n. comb.

Craterellus unicolor Berk. and Rav. Grevillea **1:** 148. 1873.
Craterellus corrugis Pk. Bull. Torr. Bot. Club **26:** 69. 1899.
Clavaria unicolor (Berk. and Rav.) Lloyd. Myc. Notes No. 64: 988. 1920.

Plates 8, 9, 10 (below) and pl. 14, figs. 5, 6

In Mycologia **32:** 415, 1940, Murrill published a note on *Craterellus unicolor* from Florida. He gave a good photograph of the plant, showing the small size

and much expanded upper end, and agreed with Burt that the spores are much more slender than those of *C. pistillaris*. He said he "felt that he was looking at a new fungus; one quite different from the *C. pistillaris* he had so often collected in the northern states."

Since our book was published in 1923, we have found in our Chapel Hill area 28 different colonies of small, simple Clavarias which vary from the typical *unicolor* form with abruptly expanded top to a slender, clavate, evenly tapering shape like small examples of *C. pistillaris*. Between these extremes we have a series of intergrading forms. Plate 22 of our book and the illustrations published herewith show a number of the variations.

Going over again all our collections from Chapel Hill, as well as a Florida plant from Murrill, it seems now that our lower piedmont and coastal plain plants are forms of the same complex and are best considered as a variety of the more typical *C. pistillaris* of our North Carolina mountains and of the northern states and Europe. While no single character has been found that is consistently distinctive of the two, the variety may be said to differ in the smaller spores, smaller size, and the much more frequent cap-like expansion of the clubs. While the spores of var. *unicolor* are, in a few cases, as large as the smallest spores of typical *pistillaris*, they average distinctly smaller, as noted by Murrill (average of 28 collections from Chapel Hill, 4.4–5.5 x 8.9–11.5 (12.7) μ. Another character that is probably significant is the habit of var. *unicolor* of growing in large to very large colonies, while *pistillaris* is usually found in smaller groups. The variety is the common form of the lower piedmont and coastal plain of the southern states, while the more typical *pistillaris* is the usual form of our mountains and in the north, though exceptions occur. According to Peck's description of his *Craterellus corrugis* and according to Burt, who has seen Peck's plants, no character can be found to separate it from the typical form of *Craterellus unicolor*. The spores of both are practically the same: for *corrugis* 8–10 x 4–5 μ (Peck) and 8–12 x 4–6 μ for the Ravenel plants (Burt). Also the size and shape are alike, even to the "obtuse margins corrugated by the extension of the hymenial wrinkles," which can be seen in several of our photographs of the southern plants. The only plants that we have been able to examine that are certainly typical *unicolor* are those from Chapel Hill, N. C., from Florida (Murrill), and a collection from Atlanta, Ga., by Mrs. Jean Williams (spores 4.2–5 x 8.5–9.3 μ). Ravenel's types are from Black Oak, South Carolina.

We give below a description of the variety and its forms, as we have them.

Gregarious in large colonies (15–125), single or some cespitose in small numbers (two or three or more), very variable in size and shape, tapering below to a thick, terete, white root, blunt at base and deeply inserted when in thick humus; color when young flesh pink with a light tint of violet or (in No. 14054) red-brown (tawny to ochraceous tawny, Ridg.) or more rarely a pale creamy brown, the stem much paler but darker when rubbed, drying about snuff-brown to bister, paler downward; flesh white, solid below, becoming soft and often hollow above; taste mildly bitter.

Spores abundant, pure white, smooth, subellipsoid, narrowed to a lateral apiculus, (4)4.4–5.5(6) x (7.4)8–12(14)μ; basidia 4-(rarely 2-)spored, 7–8μ thick; hymenium about 65–75μ thick.

In deciduous (rarely mixed) woods in the lower piedmont and coastal plain of the southeastern states.

We have in Chapel Hill both the typical form of *unicolor*, which we are calling Form A, and a slender, clavate, usually taller plant, which we are calling Form B. In all cases the hymenium, which may be rugose or smooth, descends for one-half to three-fourths of the club. These two forms may be separately described as follows.

A. Typical form.

Plants 3–6 cm. tall, expanding distally and more or less abruptly into an irregularly lobed and plicate cap-like mass, usually with a large, paler, sterile central disk which often splits and collapses later into a large cavity in the stem. In many if not all cases where the disk is large the hymenium curls up around the edge as an elevated wrinkled border.

B. Pistillate form.

Plants 5.5–11.5 cm. tall, shaped as in *C. pistillaris*, regularly clavate or more or less swollen and rugose or nodulated above, the tip usually rounded and fertile and rarely punctured into the stem cavity.

The plant described by Patouillard (Bull. Soc. Myc. Fr. **23**: 71. 1907) as *Clavaria mira* from Indo-China would seem from the description to be very like the slender examples of this form.

Clavaria pulchella Boud. Bull. Soc. Myc. Fr. **3**: 146. 1887.

C. exigua Peck. Rept. N. Y. St. Mus. **54**: 155. 1901.

Plate 1 (above) and pl. 12, figs. 1, 2

A very small, branched species of the form and size of *C. crocea* but even more dainty and delicate. Total height up to 1.8 cm., the stalk up to 5 mm. long, 0.5 mm. thick, attached by a more or less obvious little mat of mycelium; openly and mostly dichotomously branched 2–4 times and compressed at the angles like an antler, the tips subacute; main branches somewhat thicker than the stalk, about 0.7 mm.; stalk white at base, gradually taking a tint of lavender upward into the pale, translucent lavender (about grayish lavender, Ridg.) of the main body; texture very delicate and tender but not brittle and so pliable as to bend on self without cracking; withering quickly on exposure and turning pale brown, beginning with the stalk. Spores (print) white, smooth, subglobose, 2–3 x 2.8–3.7(4)μ; basidia 2–4 spored, 3.8μ thick, sterigmata short; hymenium about 37–40μ thick; no cystidia; threads of flesh closely packed longitudinally, most about 4μ thick; no clamp connections seen.

Both Boudier and Cotton and Wakefield (as *C. Bizzozeriana*) give the basidia as 2–4-spored and we find this to be obviously the case in our plants. For illustrations of other fresh plants, see Boudier (l.c., pl. 13, fig. 2^{a-d}). His fig. 2c is nearest the color of our plants. See also Burt's illustration of the type of *C. exigua* (Ann. Mo. Bot. Gard. **9**: pl. 8, fig. 64. 1922). So far as we know, this

has been reported in America only from New York by Peck as *C. exigua*. See our *Clavarias of the United States and Canada* for other synonyms.

North Carolina. Chapel Hill. No. 14009. Forming a closely set colony of about a dozen plants, none cespitose, the smallest one a simple unbranched thread only 5 mm. high, in old duff of frondose woods south of the dam at University Lake, Oct. 20, 1945. J. N. Couch, coll.

Clavaria purpurea Müll. Flora Danica, pl. 837, fig. 2. 1780.

C. nebulosa Pk. Bull. Torr. Bot. Club **25:** 326. 1898.
C. fumosoides Kauff. Pap. Mich. Acad. Sci. Arts and Let. **8:** 145. 1927.
C. occidentalis Zell. Mycologia **21:** 97, fig. 1. 1929.

Plate 13, figs. 6–15

Since Kauffman called attention to the presence of cystidia in the hymenium of *C. purpurea* (cited above and ibid., **1:** 124, 1921, as *C. fumosa*), we have gone over again all the plants in our herbarium that we have determined as *C. purpurea* and find that they all have cystidia. These are scattered or plentiful, hyaline, thin-walled with the walls often undulating and usually encrusted with a few or many granules (crystals?), general shape subcylindrical, obtuse at tip or rarely with a knob on the end, narrowed below, very variable in size, projecting 22–45 μ (see drawings).

Kauffman also finds that Peck's type of *C. nebulosa* has cystidia, which further confirms our conclusion that it is the same as *purpurea*. Wehmeyer (Mich. Acad. Sci. **20:** 255. 1934, pub. 1935) has restudied the type of Kauffman's *C. fumosoides* and finds somewhat larger spores than Kauffman originally published and thinks it is only a form of *purpurea*. Through the kindness of Dr. A. H. Smith, we have also examined the types and find that this is correct (our measurements of spores, 3.5–4.2(4.6) x 7.4–9(10) μ, many smaller that seem to us immature; cystidia present).

Dr. Zeller has kindly sent us his type plants of *C. occidentalis*, and we find that they agree with our various collections of *purpurea*. Cystidia are present and easily found, encrusted with granules as he describes and figures them. As to the spores, there is an odd discrepancy. They are described as asperulate, 6–8 x 3–4 μ, but in the drawing they appear perfectly smooth. Doty (Ore. St. Mon., Stud. in Bot. No. 7) in his description gives the spores as asperulate and his drawing (very highly magnified) shows them as minutely rough, but at the end of his discussion he says some of the spores of the type are smooth. We have examined the type spores very carefully (under both oil and water immersion) and several of our staff have agreed with us that the wall of the spore is smooth, the appearance of roughness in some cases being due to the contents; our measurements are 3.5–4 x 6.5–8.5(9.3) μ. Two of the plants are taller than any others we have seen but most of them are smaller, agreeing in size with ours, which are also quite variable in this respect. They are about wood brown in color, much wrinkled and not reviving in water except that the flattened sides open somewhat to show a hollow with scattered fragments.

In reviewing all of our specimens as above mentioned and also one from Highlands, N. C. (No. 10265), we find that the collection from Fort Bragg, on which (in the fresh state) the description in our Clavaria book was based, is different enough in several respects to make it desirable to treat it as a variety, which follows after a revised description of *C. purpurea* given herewith.

Plants simple, gregarious in large numbers, cespitose or single, subfusiform, narrowed toward tip and base; stem short, ill-defined, glabrous except for the plush-like base; color cloudy purple-gray or smoky purple, becoming more brown in fading, base whitish; context tender, easily splitting but not very brittle, subtranslucent, color of surface near periphery, whiter in the softer center, soon becoming more or less hollow but not with a distinct central cylinder; odor faintly musty, taste none.

Spores (of plant from Sweden; Romell) subellipsoid, proximal end slightly curved, smooth, 3.6–4 x 8.5–10μ. Hymenium (Smith Nos. 15946 and 19005) when wet again after drying, about 50–60μ thick; basidia 6.6–7.4μ thick, 4-spored; cystidia present, usually plentiful, varying in size, up to 11μ thick, irregular, subcylindrical to club-shaped, etc., usually with a few or many granules.

Found under conifers or in open places in coniferous woods.

When dried the plants are brown, near wood brown if dried from the quite fresh state or darker if dried after fading. The sides collapse completely and are much wrinkled on the flat surfaces.

This species differs from *C. fumosa* in the presence of cystidia, tint of purple when fresh, and larger spores of different shape. Both of these species expand somewhat when rewet, showing a large hollow with scattered filaments of the central flesh, surrounded by a rather thin wall made up of the hymenium and an rregular layer of dense tissue below it.

Illustrations: Burt. Ann. Mo. Bot. Gard. **9**: pl. 8, fig. 72 (type of *nebulosa*). 1922.
Doty. Ore. St. Monog., Stud. in Bot. No. 7: pl. 2, fig. 2 (as *occidentalis*; spores shown as rough); fig. 9 (as *fumosoides*). 1944.
Zeller. Mycologia **21**: 97, fig. 1 (as *occidentalis*). 1929.

North Carolina. Highlands. No. 10265. In mossy humus in mixed woods, pines, etc., Aug. 30, 1936.
Idaho. Below Lick Creek Summit, Idaho National Forest, Aug. 2, 1941. "Common under spruce." A. H. Smith, coll. No. 15946. Spores ellipsoid, smooth, 3.7–4.3 x 8.5–10(11)μ.
Colorado. Leal and Tolland. Kauffman (as *fumosa*, Pap. Mich. Acad. Sci. **1**: 124, 1921; see correction, ibid., **8**: 144, 1927).
Washington. Lake Quinault, in grassy place, Oct. 20, 1925. (Type of *fumosoides*).
Oregon. Mt. Hood. Under spruce and fir, Sept. 20, 1944. A. H. Smith, coll. No. 19005. Spores 3.7–4.2 x 7.5–9.3μ.
Waldport. On humus among moss, Dec. 8, 1927. (Type of *occidentalis*).
California. Crescent City. Under redwood and spruce, Oct. 30, 1937. A. H. Smith, coll. No. 8292.
Sweden. Romell, coll. Sept. 1902.

Clavaria purpurea var. **australis** n. var.

Plate 13, fig. 16

This variety differs from the species in smaller average size (2.5–6.5 cm. tall), the dried plants more twisted and curled, more rigid and nearly black, and spores slightly longer, 3.7–4.2 x (8.5)9–11(12) μ. Cystidia are present, about 7–10 μ thick. It also differs widely in habitat, occurring in very sandy soil in Fort Bragg Reservation in the coastal plain of North Carolina, in an open place left by a dead pine in a second growth forest of long-leaf pine, while the species, so far as known in America, is found only in high latitudes or altitudes: Newfoundland, Nova Scotia, Idaho, Colorado, Washington, Oregon, California, and in the Blue Ridge Mountains of North Carolina (Highlands).

Illustrations: Coker. Clavarias of the U. S. and Can., pl. 8 and pl. 82, figs. 9, 10(as *C. purpurea*).

North Carolina. Fort Bragg. No. 4860 (type of var.). Scattered singly in large numbers or a few in small clusters, in sandy soil in a long-leaf pine forest, April 14, 1921.

Clavaria taxophila (Thom) Lloyd. Myc. Notes No. 64: 1008, fig. 1856. 1920.

Craterellus taxophilus Thom. Bot. Gaz. **37**: 215, figs. 1–8. 1904.

Plate 14, figs. 13–16

Plants small, 8–33 mm. high, simple, scattered, narrowly club-shaped or trumpet-shaped, expanding at the top into a concave or flattish shallow cup 4–9 mm. wide with the marginal rim crisped and crenulated, rarely reflexed; pure white when young and fresh, becoming more ochraceous, especially above, in age. Stem not well defined, solid, smooth, pruinose, remaining white at base, which is sparingly hairy. Hymenium covering upper two-thirds or one-half of plant, delicately fluted or smooth above and extending to the very margin of the cup; inner surface of the cup *sterile*, set with very short, delicate threads up to 22μ long; hymenium in section deep brownish yellow, 25–40μ thick, including numerous irregular, swollen and constricted threads ("cystidia"), scarcely projecting, with somewhat denser contents, as shown by Thom (figs. 6 and 8); basidia 4-spored, delicate, 4–5μ thick; threads of central flesh irregular, branched and interwoven, most about 6–8μ thick but often larger, with frequent cross walls. Spores white, very small, smooth, subglobose, 2–3 x 3–4μ.

Dried plants are usually clear orange yellow throughout except for white base and at times paler margin of the concave apex.

On fallen leaves and twigs of conifers or in mixed leaves and twigs of conifers and birch.

Through the kindness of Dr. A. H. Smith and of Dr. Maxwell Doty we have been able to see and examine a number of collections of this interesting little plant, and from them have drawn up the above description. Dr. Doty's specimens (No. 2081) are just like the others, but the photograph he gives (1944: pl. 6, fig. B), taken from a collection now apparently lost, does not, in our opinion,

represent this species, and he too in a recent letter expresses strong doubt of its correctness.

Illustrations: Doty. Ore. St. Monog., Stud. in Bot. No. 7: pl. 2, figs. 7, 8. 1944.

New York. Ithaca. Under prostrate branches of *Taxus canadensis*, in Fall Creek gorge, fall of 1903. (Type of *Craterellus taxophilus*).

Warrensburg. On mixed twigs and leaves of birch and conifers, Sept. 10, 1934. A. H. Smith, No. 759. Spores small, oval, smooth, 2–2.8 x 2.8–3.8μ.

Oregon. Linn County. In fir woods, seemingly attached to dead leaves of *Pseudotsuga taxifolia*, Oct. 25, 1941. F. P. Sipe, coll. (M. Doty Herb. No. 2081).

California. Crescent City. On spruce needles on the ground, Nov. 18, 1937. A. H. Smith, No. 8871.

Another collection from Crescent City under conifers, Dec. 7, 1937. A. H. Smith, No. 9499. Spores 2–3 x 3–4.2μ.

Craterellus cristatus Kauff. Pap. Mich. Acad. Sci. Arts and Let. **11**: 172. 1930.

The type of *Craterellus cristatus* Kauff., kindly loaned us by Dr. Bessie Kanouse, consists now of six quite simple little plants growing on wood, up to 1.5 cm. tall (dry), two of them fused at base; all now fallen from the wood but several of them leaving footprints consisting of a spreading mat of brown fibers fused into a tissue, the larger fibers obviously radiating from the center but fading near the margin into a narrow region of very thin film, the whole pad about 3 mm. in diameter. In the center of the pad, where the plant broke off, is a slightly elevated circle, blackish in section, surrounding a disk of soft whitish tissue. The tops of the plants are flaring and one of them is more complicately fringed than the others, as shown by Kauffman. Cross sections from near the center of the plant show a very dark tough cortex consisting of the hymenial layer about 60–75μ thick and a subhymenial layer of more or less equal thickness, and the central, sharply differentiated region of paler, loosely woven fibers. Stained microtome sections (longitudinal) of the upper quarter of a plant clearly show that, contrary to Kauffman's description, the inner surface of the apical cup is sterile, with no trace of a hymenium. The hymenium covers the outside of the cup almost if not quite to the tip of the flange and continues downward over the club. In the dry state the lower limit is not obvious to the naked eye, but Kauffman says it descends to about 5 mm. from the base.

Spores hyaline, smooth, cylindric, 2–2.5(2.8) x 4.8–6.5μ; threads of basal pad irregular, wavy, rarely branched, 2–4μ thick, walls varying in thickness, sometimes nearly closing the lumen, cross walls few.

The dried plants are dark brown, nearly blackish except for the inside of the flaring tip which is lighter brown.

It would seem from their form and structure that this species and *Clavaria taxophila* are closely related and should be included in the same genus. It is also obvious to us that *pyxidata* (including *coronata* Schw. and *piperata* Kauff.) should be put in the same group. Dr. Doty has written us that he has in press a study of this group and is proposing a new genus, but he does not say just which species he intends to include in it. This being the case, we will not here propose any change in genus for *Crat. cristatus*.

Illustrations: Kauffman. Pap. Mich. Acad. Sci. Arts and Let. **11**: 173, fig. 3. 1930.
Doty. Ore. St. Monog. Stud. in Bot. No. 7: pl. 2, figs. 10, 11 (as *C. coronata* Schw. in error); pl. 6, fig. B (as *C. taxophila*). 1944.
Overholts. Mycologia **32**: 259, fig. 10. 1940.

Oregon. Takilma. On partly decayed logs of Douglas fir, Dec. 5, 1925. C. H. Kauffman, coll. (type).
Benton County, near Corvallis. On rotten wood, Nov. 14, 1937. W. B. Cooke No. 9833 (sent us by Dr. Doty as *C. coronata*).

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EXPLANATION OF PLATES

PLATE 1

Clavaria pulchella. No. 14009 (above).
Clavaria cretacea, type. No. 13045 (below). Both nat. size.

PLATE 2

Clavaria cinereoides. No. 5664 (above).
Clavaria Raveneliana, type. No. 12971 (below). Both nat. size.

PLATE 3

Clavaria cristata. No. 13713. Nat. size.

PLATE 4

Clavaria appalachiensis. No. 20278 (Overholts; above); No. 21227 (Overholts; right, below); No. 13330 (Highlands, N. C., left, below). Slightly reduced.

PLATE 5

Clavaria biformis (above). No. 12976 (left); No. 13060 (right).
Clavaria contorta (below). No. 23123 (Overholts). Both nat. size.

PLATE 6

Clavaria falcata. No. 12864 (above); No. 13520 (left, below); No. 13388 (right, below) Nat. size.

PLATE 7

Clavaria luteo-alba form *montana*. No. 12617 (top); No. 12710 (center); No. 5571 (bottom). All nat. size.

PLATE 8

Clavaria pistillaris var. *unicolor*. No. 13223 (above); No. 13239 (below). Nat. size.

PLATE 9

Clavaria pistillaris var. *unicolor*. No. 13950 (above, intermediate form); No. 10344 (below). Both from Chapel Hill, N. C.

PLATE 10

Clavaria pistillaris, intermediate form. Vaughn, N. Y. (Burnham, No. 71, above). Dried plants, nat. size.

Clavaria pistillaris var. *unicolor*. No. 13960. Chapel Hill, N. C. Very slightly reduced.

PLATE 11

Clavaria subfennica. No. 12879, type, and No. 13378 (above). About ½ size.

Clavaria Invalii. No. 12991 (below). Nearly nat. size.

PLATE 12

Fig. 1. *Clavaria pulchella*. No. 14009. Spores. × 1620.
Fig. 2. Same, showing 4-spored and 2-spored basidia. × 810.
Fig. 3. *C. Raveneliana*. No. 12971 (type). Spores. × 1620.
Fig. 4. Same, showing irregular threads of flesh and (left) basidium. × 502.
Fig. 5. *C. subfennica*. No. 12879 (type). Spores. × 1620.
Fig. 6. *C. subfennica*. No. 13378. Bit of hymenium. × 810.
Fig. 7. *C. cretacea*. No. 13045 (type). Spores. × 1620.
Figs. 8–10. Same, showing bit of hymenium with imbedded cystidia, cystidia shown separately, and one basidium. × 810.
Fig. 11. *C. cystidiophora*. No. 16258 (Shuksan Inn, Wash., A. H. Smith). × 502.
Fig. 12. *C. cystidiophora*, type. Bits of hymenium with projecting cystidia. × 502.
Fig. 13. Same, type. Spores. × 1620.
Fig. 14. *C. cystidophora*. No. 16258. Spores. × 1620.

PLATE 13

Fig. 1. *Clavaria rufobrunnea*. No. 9403. Basidium and sterile threads. × 810.
Fig. 2. Same. Spores. × 1620.
Fig. 3. *C. maricola*. No. 8929. Spores. × 1620.
Fig. 4. *C. maricola*, type. Spores. × 1620.
Fig. 5. *C. nebulosoides*, type. Spores. × 1620.
Fig. 6. *C. fumosoides*, type. Cystidia and sterile clubs. × 810.
Fig. 7. *C. fumosoides*, type. Spores. × 1620.
Figs. 8, 9. *C. purpurea*. A. H. Smith, No. 19005. Cystidia, basidia, and sterile clubs. × 810.
Fig. 10. *C. purpurea*. No. 15946. Encrusted cystidia and sterile clubs. × 502.
Fig. 11. *C. purpurea*. No. 10265. Cystidia and sterile clubs. × 810.
Fig. 12. *C. purpurea*. Sweden (Romell, coll.). Encrusted cystidia. × 810.
Fig. 13. *C. nebulosa*, co-type. Encrusted cystidia. × 810.
Fig. 14. *C. occidentalis*, type. Spores. × 1620.
Fig. 15. *C. occidentalis*, type. Encrusted cystidia. × 502.
Fig. 16. *C. purpurea* var. australis. No. 4860. × 810.

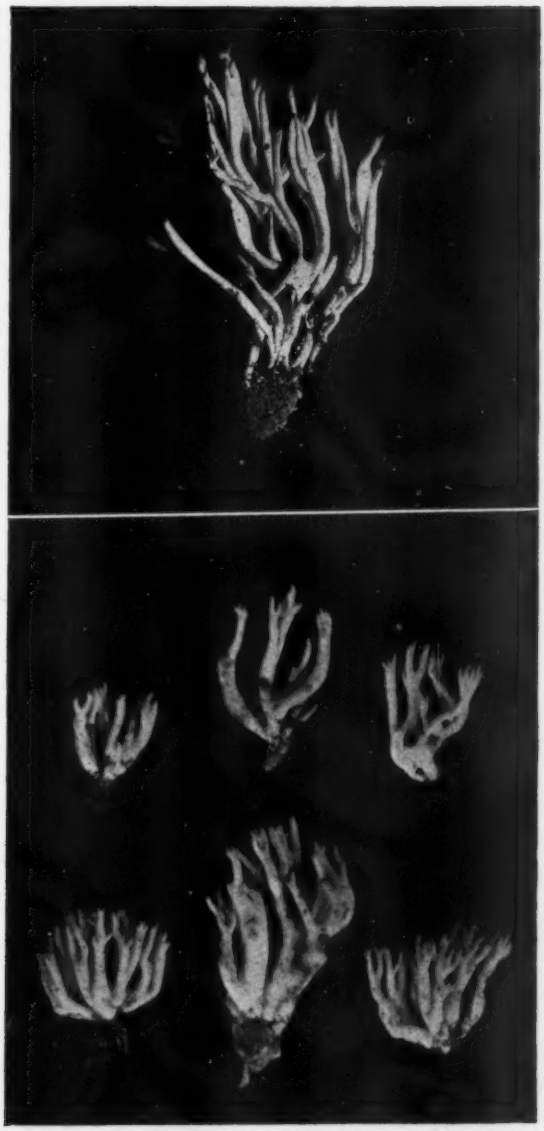
PLATE 14

Fig. 1. *Clavaria falcata*. No. 13388. Spores. × 1620.
Fig. 2, 3. *C. falcata*. No. 12864. Thread with clamp connections; basidium and sterile clubs. × 810.

Fig. 4. *C. luteo-alba* form *montana*. Spores. × 1620.
Fig. 5. *C. pistillaris* var. *unicolor*. No. 13223 (Chapel Hill, N. C.). Spores. × 1620.
Fig. 6. *C. pistillaris* var. *unicolor*. No. 4770 (Chapel Hill, N. C.). Spores. × 1620.
Fig. 7. *C. pistillaris*. No. 8354 (Linville Falls, N. C.). Spores. × 1620.
Fig. 8. *C. pistillaris*. Burnham, No. 71 (Vaughns, N. Y.). Intermediate form. Spores. × 1620.
Fig. 9. *C. pistillaris*. No. 27 (Redding, Conn.). Intermediate form. Spores. × 1620.
Fig. 10. *C. "truncata"*. Nauchatel, Switzerland (P. Konrad, coll.; Lloyd Herb.). Spores. × 1620.
Fig. 11. *C. globospora*, type. Basidia and sterile clubs. × 810.
Fig. 12. *C. globospora*, type. Spores. × 1620.
Fig. 13. *C. taxophila*. No. 8871. Section of top of a plant, showing sterile area on concave tip and hymenium down the sides. × 52.
Fig. 14. *C. taxophila*. No. 9499. Spores. × 1620.
Fig. 15. *C. taxophila*. No. 9499. Basidium and sterile clubs. × 810.
Fig. 16. *C. taxophila*. No. 9499. Entire plant (right), ¼ nat. size; upper part (left), × 6. Drawing by Alleda Burlage.

PLATE 1

PLATE 2



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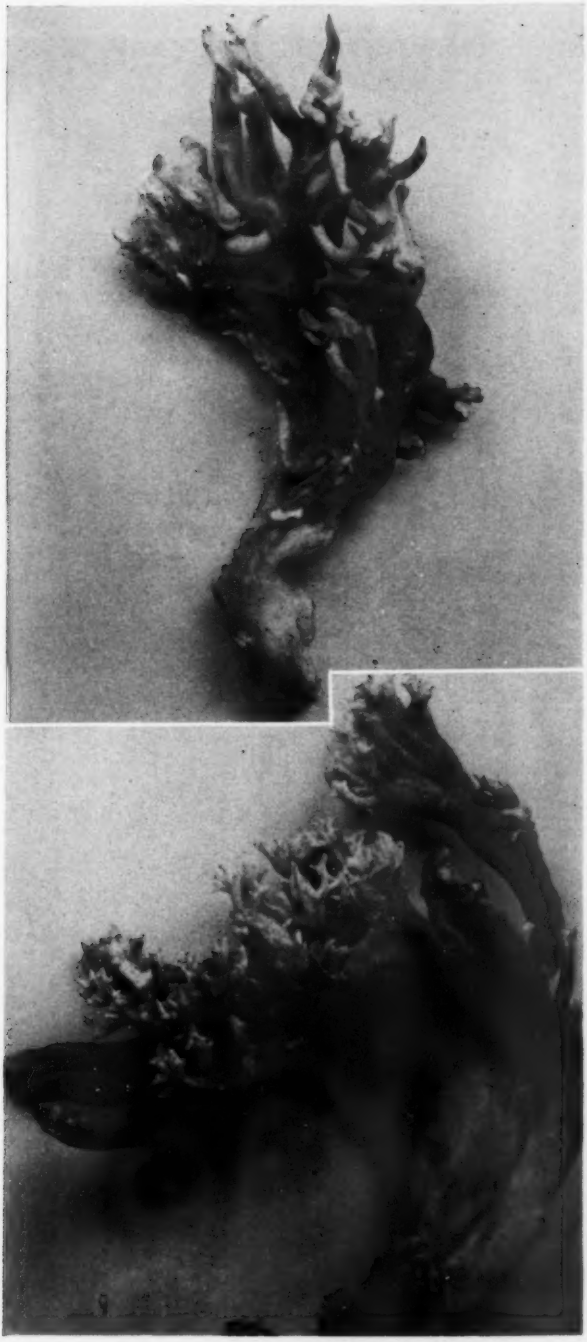

PLATE 4

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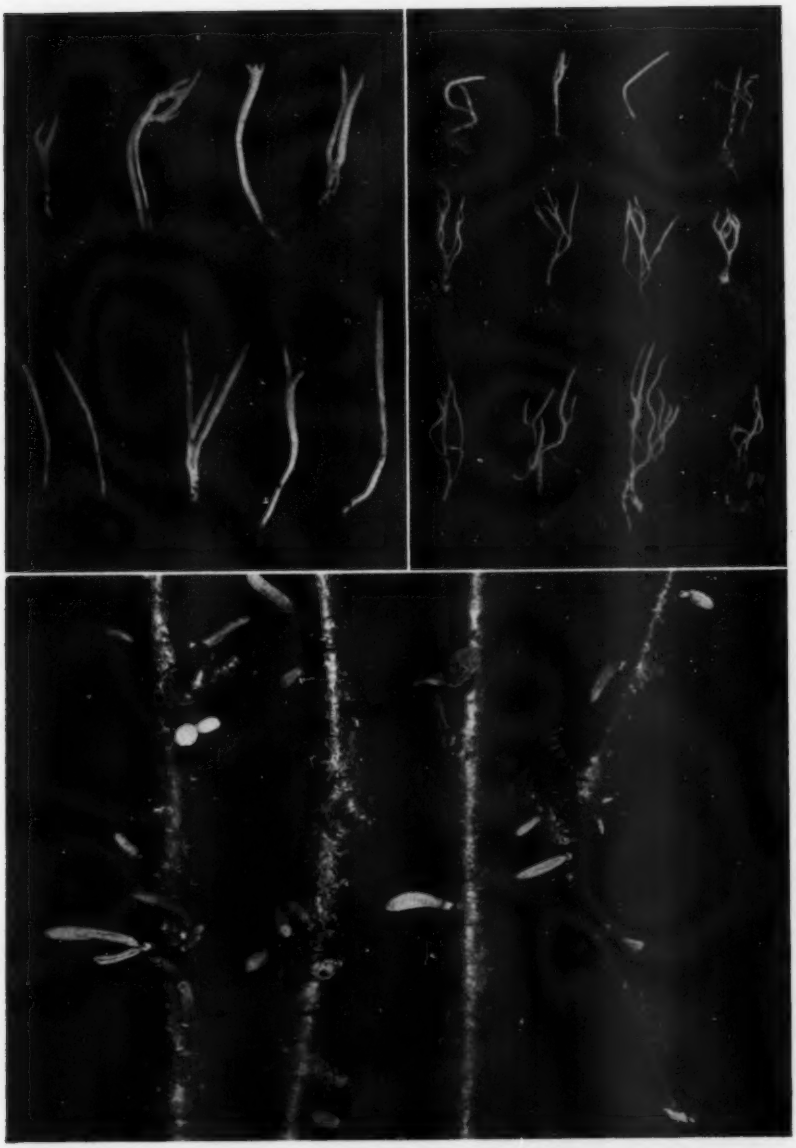

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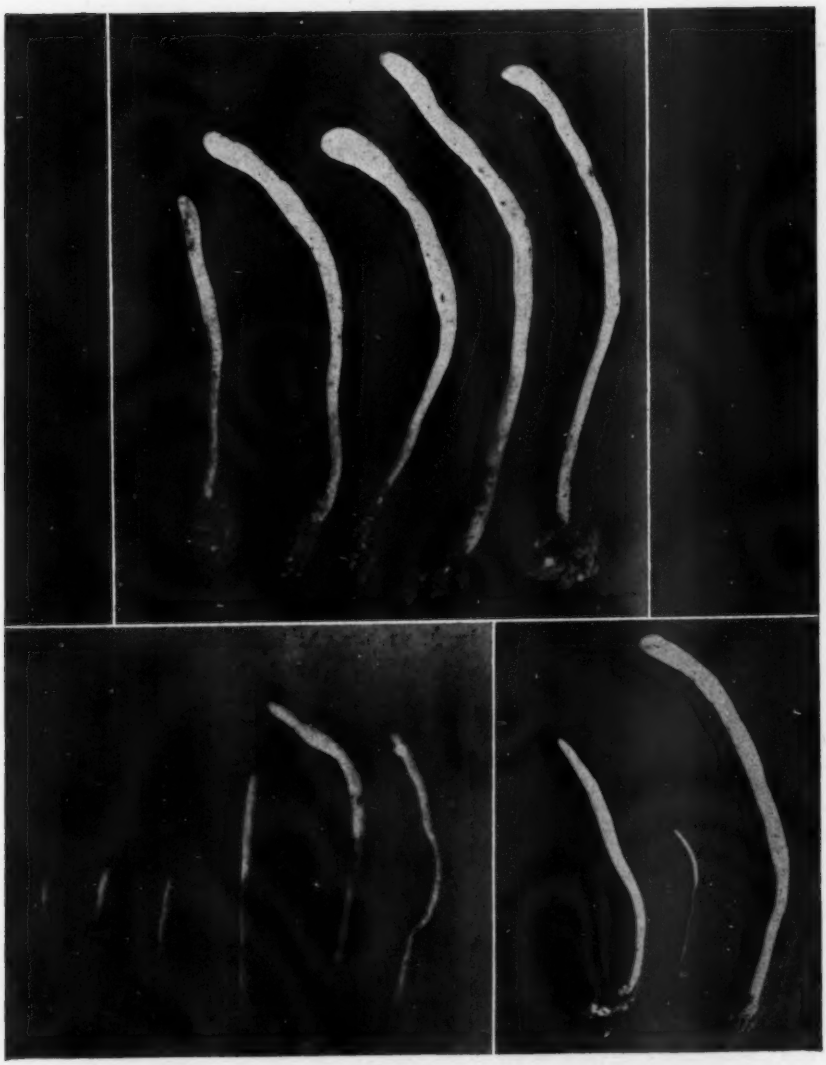


PLATE 7

PLATE 8

PLATE 9

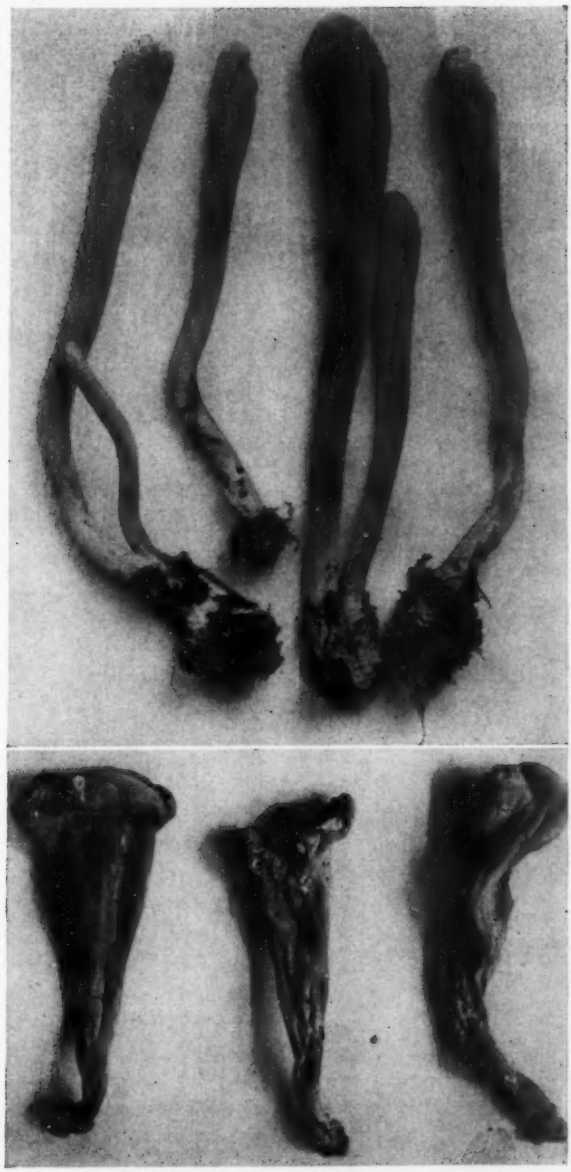


PLATE 10

PLATE 11

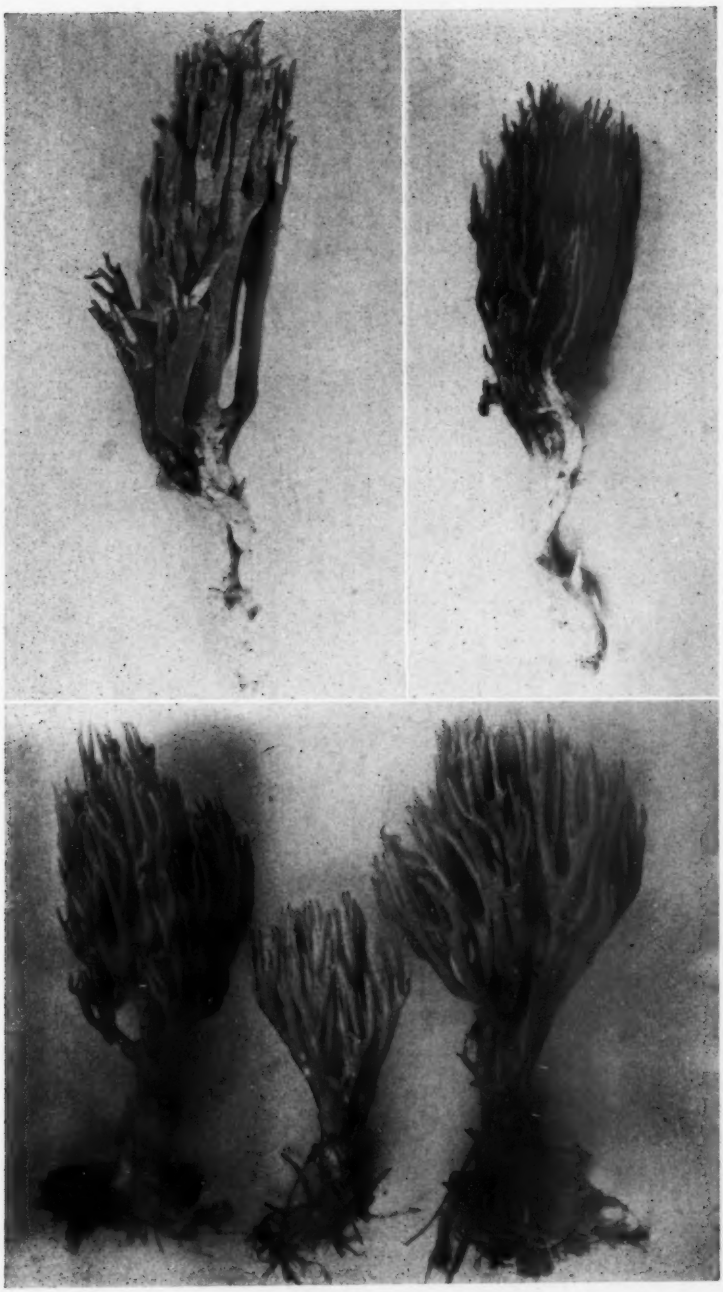


PLATE 12

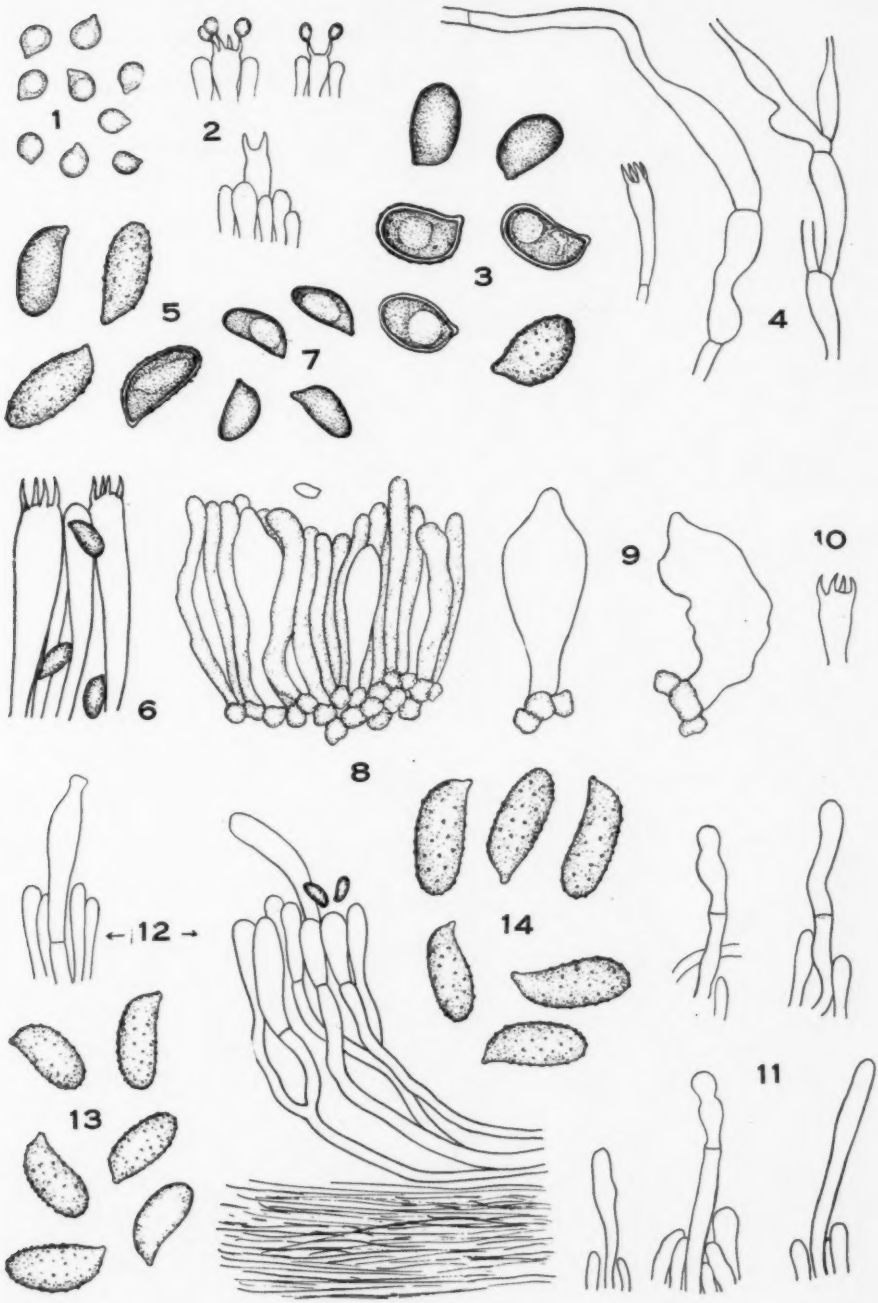


PLATE 13

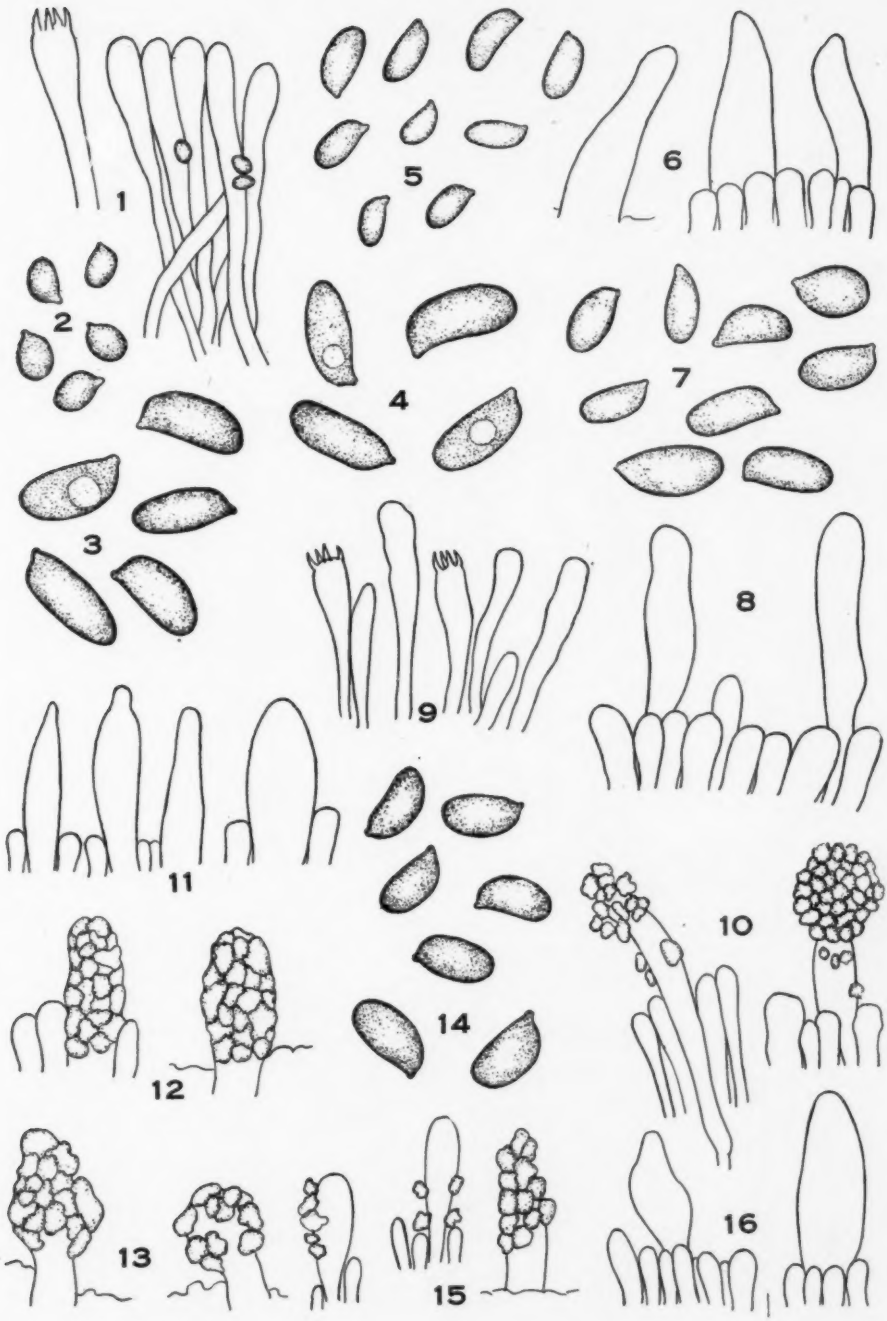
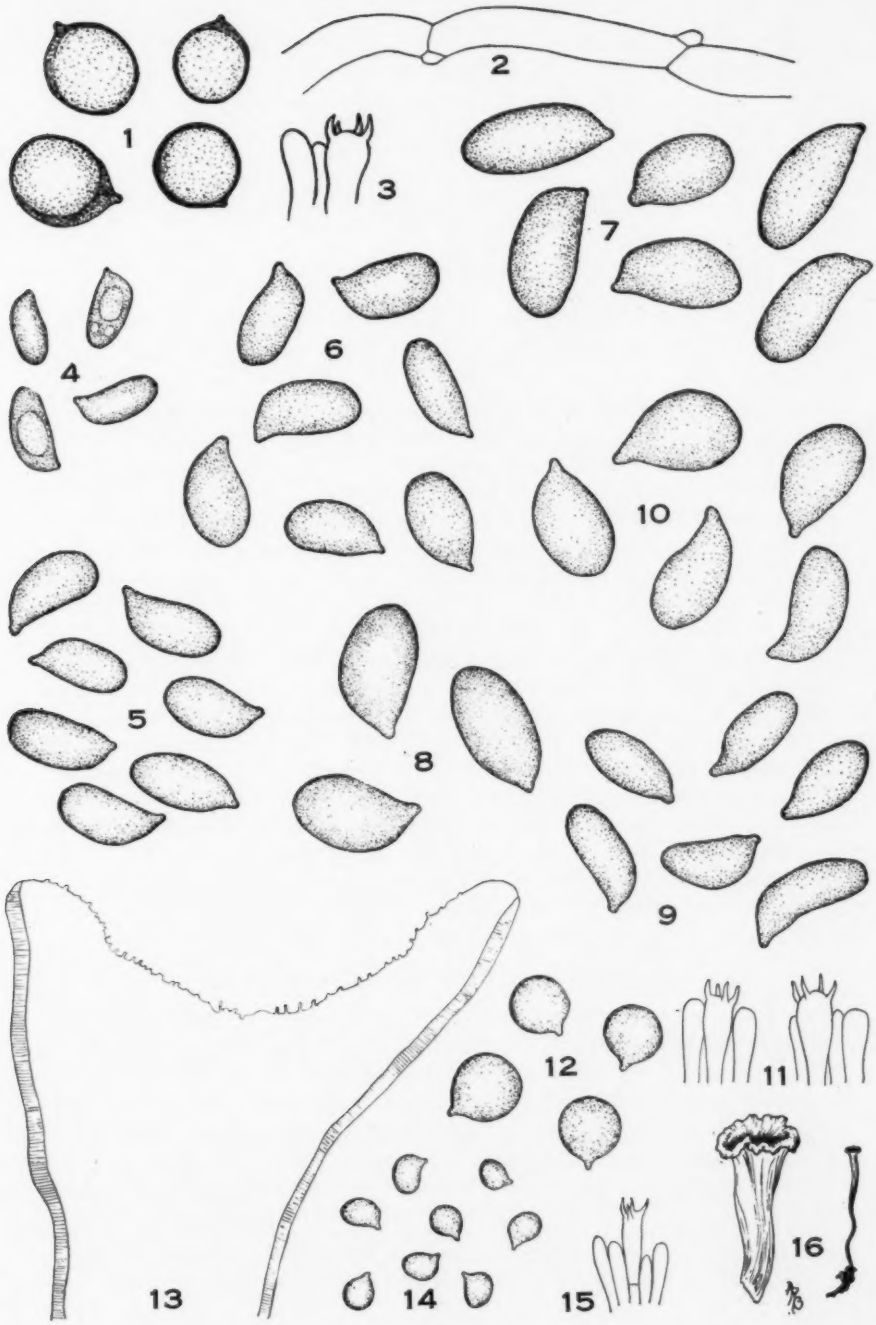


PLATE 14



FURTHER OBSERVATIONS ON COELOMOMYCES, PARASITIC ON MOSQUITO LARVAE

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and H. R. Dodge[1]

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Plates 15–20

Since the publication of my first paper (1945) on *Coelomomyces*, large numbers of parasitized mosquito larvae have been sent to me by Mr. Dodge from Georgia. A study of these has brought to light several undescribed species and additional information about the old ones. In fresh material sent, sporangial germination has been followed in several species, corroborating in the main the observations of De Meillon and Muspratt (1943). Attempts to infect larvae of *Anopheles crucians* in petri dishes by the addition of zoospores from germinated resting sporangia of *Coelomomyces dodgei* have been unsuccessful. However, both Walker (1938) and Muspratt (1946b) have been able to get infection of *A. gambiae* larvae hatched from eggs by putting such larvae into large shallow concrete troughs filled with rain water to which had been added, in the latter's experiments, many air-dried sporangia of the fungus and air-dried mopane clay soil from the region where the fungus was collected.

According to the observations of Dodge, the ratio of infected larvae to healthy ones is so small that it would seem from the data at hand that these parasites are of little importance in reducing the population of mosquitoes. Muspratt (1946a), however, estimated the mortality of *Anopheles gambiae* due to a species of *Coelomomyces* to be as high as 95% from 1941 to 1945. More studies are needed before any conclusions can be drawn as to the possible effectiveness of *Coelomomyces* in the biological control of mosquitoes.

SPORANGIAL GERMINATION IN COELOMOMYCES

The first to observe sporangial germination in *Coelomomyces* were De Meillon and Muspratt (1943). I also reported sporangial germination in my first paper but gave no details. In fresh material sent by Dodge in January, February, May, and November germination has been observed in *C. dodgei*, *C. punctatus*,

[1] The mosquito larvae used in this study were collected in Georgia by inspectors of State Malaria Control in War Areas and sent to Mr. Dodge, Assistant Entomologist, at Macon. He sorted out and identified the parasitized larvae and sent them, together with all the field notes, to Dr. Couch who studied the fungi, made the drawings, and wrote the paper. The symbols following the names of towns indicate individual stations.

The writer gratefully acknowledges the technical assistance of Miss Josephine Stewart in this work, and also the grant from the Smith Fund which made her help available.

and *C. lativittatus*. The observations on *C. lativittatus* were the most complete and will be described here. Material of this species dated Jan. 23, 1945, was received Jan. 26, 1945. The infected mosquito larvae were already dead but their bodies had not disintegrated. One heavily infected larva was cut into three parts and one part was put in a petri dish of charcoal water with a small branch of *Elodea*, and the other two parts were put in separate dishes in charcoal water. Each fragment of larva, containing masses of resting sporangia, was examined daily to discover signs of germination. None of the material was dried and six days after it had been collected some of the sporangia had started germinating. On Jan. 29 about noon a few sporangia were seen to have a slight bulge on one side, and in others the swelling had gone far enough to split the outer wall along the preformed line, exposing the inner sporangial membrane (pl. 15, figs. 1, 2). By this time the lipoid granules, which had been more or less evenly dispersed throughout the cytoplasm, had aggregated in spherical groups, each group destined to be the center of a spore origin, a stage characteristic of other members of the Blastocladiales. About six to twelve hours after the opening appeared in the outer wall the contents of the sporangium, surrounded by the thin inner membrane, had pushed out through the slit to form a dome-shaped extension (pl. 15, fig. 3). At this stage the spherical aggregates of lipoid granules were very distinct. Observations were stopped at 10:00 p.m. and resumed the following day at 9:00 a.m., at which time many empty sporangia as well as sporangia about to discharge spores were seen.

The series of drawings (pl. 15, figs. 4–8) shows late stages in zoospore development and discharge. The swelling of the internal contents of the sporangium continues until it reaches its maximum, when the slit in the outer wall extends from one-half to two-thirds the length of the sporangium and is broadly elliptical in outline. The protoplasm, surrounded by the inner wall layer, protrudes through this opening as a slightly flattened hemispheric mass in side view, but is really about twice as long as wide. At this stage the spore outlines are distinct and are polygonal from pressure (pl. 15, fig. 4). With a water immersion objective the nuclear cap and nucleus, with the lipoid granules beside it in a clump (pl. 15, fig. 9), are readily seen. The first indication that the spores are about to emerge is the gelatinization of the wall surrounding the protruding spore mass (pl. 15, fig. 5). This takes about ten minutes, during which the membrane increases to four or five times its original thickness (pl. 15, fig. 6). About three to four minutes before the spores emerge, those in the protrusion begin a rocking motion which in a few seconds spreads throughout the sporangium; and in a few seconds more the whole mass begins a slow motion which soon becomes cyclic, so that the entire mass is moving round and round in the sporangium. Suddenly at one end of the elongated, protruding mass the outer part of the gelatinous membrane breaks and the inner part seems to dissolve, and through this opening the spores rush out and swim away (pl. 15, fig. 7). In less than a minute the entire gelatinous wall disappears and all the spores emerge except for a few (pl. 15, fig. 8). These one by one find the slit, which has now become smaller, and creep through to the outside.

As shown by me (1945), the structure of the resting sporangium wall and the detailed structure of the zoospores are typical of the Blastocladiales. In the actual dehiscence of the sporangium, however, *Coelomomyces* is quite distinct from all other members of this order. My observations confirm in the main those of De Meillon and Muspratt (1943), but our interpretations of the structure of the wall around the extruded protoplasm differ. They say that two thin membranes are present and just before spore discharge become more widely separated. I have interpreted this as a single membrane which gelatinizes.

DESCRIPTIONS OF SPECIES AND VARIETIES

Coelomomyces dodgei as first understood (Couch, 1945) included resting sporangia with pits and narrow bands, with only pits, and with wide bands. With an abundance of material available, it has been found that these three sporangial types are constant and rather strictly limited as to host. In recognition of these facts, the form with pits and narrow bands occurring on *An. crucians* is herein retained as *C. dodgei* emend., the form with only pits, restricted almost exclusively to *An. quadrimaculatus*, and the form with wide bands, occurring on *An. crucians*, are described as new species.

I wish to record here also the remarkable occurrence of a rare fungus in the gut of a larva of *An. crucians*. While dissecting the bodies of *An. crucians* searching for early stages of *Coelomomyces*, I found one larva whose gut was still filled with partly digested pieces of the threads of *Spirogyra*, some of the cells of which were parasitized by the chytrid fungus *Micromyces longispinosus* (pl. 20, fig. 6). This fungus has been found only once before and then from Long Island, N. Y. (Couch, Mycologia **29**: 592. 1937).

Coelomomyces dodgei, emend.

Plate 16, fig. 1; plate 20, fig. 1

Hyphae 7–14μ thick, irregularly branched and anastomosing; sporangia 27–42 x 37–65μ, oval, sometimes slightly flattened on one side, wall deep brown, rarely hyaline, 1.5–4.2μ thick, consisting of an outer thickened hyaline to brown part (2–3μ thick) and an inner thin hyaline layer (1–2μ thick); outer part of wall with rounded or elongated pits or with narrow bands separated by grooves; not infrequently with narrow bands on one side and pits on the other; the grooves extending lengthwise or arranged in variously curved patterns. Bands about 3.6μ wide and not very distinct, with 7–10 visible on surface view. Wall with a preformed longitudinal groove along which dehiscence occurs to permit spore discharge. Germinating in water and without previous drying after the death and partial disintegration of the larva, the process occupying 24 to 36 hours. When ready to germinate, the contents swell, producing a lateral bulge and thus causing the thick outer wall to crack open at the longitudinal groove. Twenty-four to thirty-six hours later the spores emerge through this crack, surrounded by a gelatinous material which after three to five minutes disappears, allowing the spores to escape. Spores posteriorly uniflagellate, elongated and broadest at the posterior end, 2.6–3.8 x 5.2–6.3μ when swimming, 4–5μ when quiescent and rounded, with several lateral lipoid granules and an indistinct nuclear cap.

Parasitic in larvae of *Anopheles crucians*. Type from Thomasville (C186), Ga.; also from other locations in Georgia. Of the parasitic fungi so far found on mosquito larvae in Georgia, this is by far the most common, appearing in fifty-eight collections. This species may be distinguished from related forms by the resting body walls, some of which are pitted while others have narrow bands.

Coelomomyces lativittatus n. sp.

Plate 15; plate 16, figs. 2–4

Hyphae much as in *C. dodgei*, 4–10μ thick; resting bodies oval, in cross section view usually rounded, rarely flattened on one side, with wide, very distinct, longitudinal bands on one side and irregular or transverse bands on the other, very rarely with a few pits; longitudinal bands five to eight on a side, bands 4–6.3μ wide; the preformed longitudinal slit of dehiscence between the two median longitudinal bands; 29–35 x 40–58μ, rarely 36 x 77μ, average 32 x 48μ; wall 1.5–4μ thick, consisting of the outer, brownish layer with ridges 2–3μ thick and the inner, smooth, pale or hyaline layer, about 1–2μ thick. Zoospores as in *C. dodgei*.

This species occurs on the same host, *An. crucians*, as *C. dodgei*, with which it was at first included (Couch, 1945). It is easily separated from that species by the structure of the resting sporangial wall, the outer layer of which is ornamented with pits and narrow bands, while in the present species the outer wall has a banded structure and is very rarely pitted. Occurring in 25 collections from Georgia on *Anopheles crucians*. Type, Moultrie (S14) Georgia, March 28, 1945. In addition to the collections from Dodge, Dr. A. J. Walker has recently sent me 8 larvae of *An. crucians* collected April 29, 1944, near Moodie Field, Georgia, each of which was infected.

Coelomomyces punctatus n. sp.

Plate 16, figs. 5, 6

Mycelium as in *C. dodgei;* sporangia oval, slightly flattened on one side, rarely subglobose, 32–41 x 42–75μ, most 32–34 x 46–54μ; wall 1.5–3.8μ thick, consisting of an outer, pale yellow to brown layer and an inner hyaline layer, outer layer slightly thicker than inner and set with minute rounded or elongated pits which are about 0.5μ in diameter when rounded and 0.5 x 4μ or more when elongated, about 2–4μ apart; outer wall layer with a preformed longitudinal groove extending half to two-thirds the length of sporangium on one side, along which dehiscence occurs to permit zoospore discharge. Zoospores as in *C. dodgei*.

Parasitic in larvae of *Anopheles quadrimaculatus*, appearing in 22 collections from various locations in Georgia (type from Dublin). Recognized by its occurrence on *An. quadrimaculatus* and by the pitted walls. *C. dodgei*, to which it is closest, occurs only on *An. crucians* and has sporangial walls that are furnished with pits and bands and hence may easily be distinguished from *C. punctatus*. In a collection of larvae of *Anopheles quadrimaculatus* infected with this species a single larva of *An. crucians* was found also heavily infected with the same

fungus. The fungus within this single larva of *An. crucians* had resting sporangia all of which showed pits. It therefore seems unlikely that the present species is merely a physiological form of *C. dodgei*.

Coelomomyces bisymmetricus n. sp.

Plate 17, figs. 5–7; plate 18, figs. 1–4

Mycelium not so thick or well-developed as in *C. dodgei*, 3–10.5μ thick, usually about 6–9μ thick, sparingly branched and each thread of uneven diameter. Young sporangia oval with an irregular outline, outer zone of young sporangium hyaline, the central part with dense protoplasm. Mature sporangia 23–28 x 34–48μ, average 25 x 40μ, oval; wall pale brown, the outer layer with alternating high and low ridges and one conspicuous mammate structure, the ridges typically encircling the cell in such fashion as to give the wall a bilateral symmetry with a long ridge bordering one edge and thus appearing smooth, and the "ends" of the wide and narrow ridges with the mammate structure in the center on the other edge; not infrequently the ridges may be irregularly arranged; in median cross section with two wall layers, the outer typically with six wide and high elevations (sections of the large ridges) alternating with six smaller elevations (sections of the small ridges), the number of each type of elevation varying from 5 to 7. This is the usual arrangement though frequent variations from this regular pattern occur. Wall with a preformed longitudinal slit on the wide ridge opposite the mammate structure. Germination not observed.

Appearing in sixteen collections from Moultrie, Valdosta, and Thomasville, Georgia, March–July. On *Anopheles crucians*. Type, Moultrie (C137). In one collection with *Coelomomyces quadrangulatus*, both species being in the same larva. Easily recognized by the wall structure.

Coelomomyces sculptosporus n. sp.

Plate 17, figs. 1, 2; plate 18, figs. 6–9

Mycelium much as in other species; hyphae 4–17μ thick; resting sporangia 22–31 x 33–58μ, most about 27 x 45μ, oval; wall consisting of two layers, an inner, smooth one and an outer, variously sculptured one. Outer wall with high, wide ridges (4.2–6.3μ wide), usually in the form of an irregular net, the meshes rarely circular, usually oblong or elongated; rarely with the high ridges parallel on one side (usually three to a side) and irregular on the other; in longitudinal section the ridges standing out as distinct, rounded elevations, which may appear over the margin of the entire oval or on one side only, with the opposite side smooth; in median cross section the inner wall circular and smooth, the outer showing five to seven wide, high, rounded elevations with a smaller elevation 2–4μ wide between each pair; a preformed longitudinal dehiscence slit extending along the middle of one of the ridges, which may be the only longitudinal ridge.

This species has been found in thirteen collections from Georgia, occurring both on *An. punctipennis* and *An. crucians*. It belongs in the group with *C. bisymmetricus* but differs from that species in that the ridges on the wall never show the same pattern on both sides as is usual in *C. bisymmetricus*. It differs

from *C. cribrosus* in having sporangia with only a few circles and these on only one side. Type, Macon (F5), Georgia.

Coelomomyces cribrosus n. sp.

Plate 17, fig. 3; plate 18, fig. 5

Hyphae 6-11μ thick; resting sporangia 24-42 x 42-71μ, oval or slightly allantoid, i.e., appearing flattened on one side in longitudinal outline, mostly circular in outline in cross section view; wall 2-4.2μ thick, pale yellow under microscope, consisting of an inner, smooth, hyaline layer and an outer layer which is variously sculptured or rarely smooth; wall typically with 3-20 or more circular or oblong thin areas on each side, the circles being thin areas in wall between thicker ridges or bands, usually with several small, rounded or elongated pits in the thin areas; circles usually 2-6.4μ wide; wall sometimes with minute rounded or elongated pits, these small pits scattered over entire surface or sometimes arranged in two bands which border the dehiscence slit, or with thick and thin irregular bands; all resting sporangial types with interconnecting forms; in median cross section view wall showing several (usually seven to nine) more or less conspicuous rounded elevations, between each two of which is a smaller elevation, the larger ones being sections of the bands and the smaller the thin, circular areas between the bands; each resting sporangium with a preformed longitudinal slit located in the middle of the most conspicuous band.

This species has been found in the larvae of two different species of mosquito' *An. crucians* and *An. punctipennis*, in the same collection from Rome (C55), Ga., August 23, 1945. It is related to *Coelomomyces bisymmetricus* but has larger resting sporangia and a wall which, though variable in markings, is characterized by the large, thin, circular or oblong areas bordered by the thicker bands.

Coelomomyces keilini n. sp.

Plate 20, figs. 2-5

Hyphae fairly abundant and conspicuous though less so than in *C. quadrangulatus*, consisting mostly of rather short subdichotomously branched pieces, 5-25μ, usually 10-12.6μ, thick by 60-170μ long or sometimes longer, and many smaller irregularly shaped pieces. Sporangia oval in outline, usually slightly flattened on one side, 34-46 x 58-71μ; wall consisting of three layers, the outer, very thin, hyaline membrane derived from the old plasma membrane and the wall proper which is 3-7μ thick, the outer part up to 5μ thick, the inner up to 2μ. In the thinner-walled sporangia the outer wall may be smooth or with minute striae; in the thicker-walled ones the outer wall is pitted, the mouths of the pits slit-like; the pits appearing somewhat star-like as one focuses down; in section view spindle-shaped, with parallel striae between the pits. In some of the thick-walled sporangia the protoplasm has shrunken from the first formed wall layers at one end and has formed an additional wall with the old walls. Some sporangia with a preformed longitudinal slit, on others this slit not observed.

Found only once on one larva of *An. crucians* with other larvae of same species infected with *C. dodgei*, Valdosta (M 21 and 22), Ga., December 7, 1944.

Coelomomyces quadrangulatus* var. **irregularis** n. var.

Plate 19, figs. 4, 5

Mycelium well developed, much as in the typical species; sporangia roughly oval in outline but outer wall crenulated and very irregular, 15–21 x 23–41μ, with 4–6 irregular longitudinal ridges between which are numerous transverse lines; very minutely punctate; inner wall layer in longitudinal section view oval in outline, slightly flattened on one side; outer wall with 4–6 ridges in cross section, inner wall nearly rounded in the same view; outer wall with a distinct longitudinal slit on one of the ridges.

This variety has been found only once and then on a larva of *An. punctipennis* from Dublin (C9), Georgia. It is somewhat intermediate between *C. quadrangulatus* and *C. pentangulatus* but is easily separated by the very irregular walls of the resting sporangium.

Coelomomyces quadrangulatus var. **lamborni** n. var.

Through the kindness of Dr. Keilin I have been permitted to examine the type slide of *Coelomomyces stegomyiae* Keilin and find on it an additional species of *Coelomomyces* close to *C. quadrangulatus*.

Sporangia 26–31 x 36–58μ, wall transversely striate in surface view, four-angled in cross section, wavy in longitudinal section; with a distinct preformed longitudinal fissure in the outer wall layer on one side.

This variety should probably be described as a new and distinct species since the resting sporangia are distinctly larger than those of the type. It seems best, however, to leave it as a variety until fresh material can be studied.

In one larva of *Stegomyia scutellaris*, with *C. stegomyiae*, collected by Dr. Lamborn in the Federated Malay States. The occurrence of two different species of *Coelomomyces* in the same larva has been noted in several cases.

Coelomomyces sp. ?

Intermingled with typical *C. dodgei* in seventeen collections were the resting bodies of what appears to be a different and new species. The resting bodies of this species were oval, flattened on one side, with the usual longitudinal slit; 31–38 x 42–60 μ, with a pale brown, smooth to minutely pitted wall, the pits scattered or arranged in transverse lines, thus giving a striated appearance as in a diatom shell. The mycelium of this new species is indistinguishable from that of *C. dodgei*.

On *An. crucians* from Thomasville and Valdosta, Georgia, throughout the year. Material sent by H. R. Dodge.

* Since *Coelomomyces* is a masculine noun, I am adopting for future use the masculine ending for the species name.

NOTES ON OLD SPECIES

Coelomomyces uranotaeniae Couch (1945)

Plate 17, fig. 4

This species was described from a few infected larvae of *Uranotaenia sapphirina* from Thomasville (B4), Georgia, collected Oct. 9, 1944, and is one of the less common species. Since then it has been found in two other stations near Thomasville, and once each from Savannah, Valdosta, and Moultrie. The mycelium is unusual in that it is enclosed by a hyaline sheath (fig. 4). This same figure also shows resting sporangia with the characteristic transverse striations on the wall between the longitudinal ridges.

Coelomomyces psorophorae Couch (1945)

This very distinct species was described from one collection on *Psorophora ciliata* from Moultrie, Ga. Since then several collections have been received, extending the geographical and host range and making necessary certain changes in the original description. In one of these from Valdosta (M3), Georgia, May 4, 1945, there were several parasitized larvae, some of which contained mostly mature resting sporangia and very little mycelium as in the type collecton, while other larvae contained earlier developmental stages with well developed mycelium and resting sporangia in all stages of development. A third collection from Moultrie (135), Ga., July 13, 1945, was parasitic in the larvae of *Aedes vexans* and differed from material on *P. ciliata* in having slightly smaller resting sporangia (42–66 x 63–94 μ) with walls up to about 5.5 μ thick and thus only about half as thick as in the type. Recently Dr. A. J. Walker of Tulane University has sent me two slides of this species, one on *Psorophora howardii* from Charleston, S. C., July, 1942, with resting sporangia much as in the collection on *Aedes vexans* and the other on *Theobaldia inornata* from Port Sulphur, La., January, 1944. In the latter collection the resting sporangia are larger than in the type, running up to 58 x 119μ with wall up to 5μ thick.

This species shows a slight resemblance to *C. stegomyiae* Keilin, the type species of the genus, the similarity to which I was able to discover by an examination of one of Keilin's type slides which he was kind enough to lend me. The two are similar in wall structure, both having straight or diagonal pits in the thick outer wall layer. In *C. stegomyiae* the pits are usually 1.5–3 μ apart, while in *C. psorophorae* the pits are less than 1.5 μ apart and are much smaller and hence far more abundant. Also the resting bodies of *C. psorophorae* are much larger than in *C. stegomyiae*. (I have found that Keilin's measurements for the type run a little small. His figures are 20–30 x 37.5–57 μ, while I find some on his slide run up to 37 x 63 μ.)

Coelomomyces quadrangulatus Couch (1945)

Plate 19, figs. 2, 3, 6

This species was reported as rather rare when first described, but subsequent collections from Georgia have shown it to be the commonest species next to *C.*

dodgei. It has been found in 19 collections on *An. punctipennis*, in 13 on *A. crucians*, in 5 on *A. quadrimaculatus* and 1 on *A. georgianus*. In several collections I have found resting sporangia a few of which in end view showed three or five angles, the latter resembling *C. pentangulatus* Couch. These two species are easily separated by their resting sporangia and also by their mycelia, which in *C. quadrangulatus* is the most vigorous of any seen so far and does not break up into much-branched pieces (pl. 19, figs. 1–3).

SUMMARY

Germination of the resting sporangia of *Coelomomyces dodgei*, *C. punctatus*, and *C. lativittatus* has been observed. In all three species germination occurred about a week after the infected larvae had been collected, and without previous drying of the resting bodies. When germination starts the contents swell and cause the outer wall to split along a preformed line. The contents of the sporangium continue slowly to swell, bulging out through the fissure to form a dome-shaped mass surrounded by the inner spore wall. Twenty-four to thirty-six hours later the zoospores are formed and the entire exposed part of the inner wall quickly swells and dissolves to set the zoospores free. In structure and method of swimming the zoospores are typical of the Blastocladiales.

The species *Coelomomyces dodgei* as originally understood is broken up into three species, *C. dodgei*, *C. lativittatus* n. sp. and *C. punctatus* n. sp. Four other new species, *C. bisymmetricus*, *C. sculptosporus*, *C. cribrosus*, and *C. keilini* and two new varieties of *C. quadrangulatus* are also described, and some additional notes on old species are given.

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EXPLANATION OF PLATES

PLATE 15

Fig. 1. Resting sporangium of *C. lativittatus* just beginning to germinate, showing outer wall splitting on side to right. Coll. from Douglas, Ga., Jan. 23, 1945. Drawn Jan. 29, 12:45 p. m. × 1216.

Fig. 2. End view showing slightly later stage. 1 p.m. × 1000.

Fig. 3. Side view showing contents of sporangium pushing out through slit. Note distinct circles of lipoid granules. 10 p.m. × 1216.

Figs. 4–8. Sketches made from a single sporangium of late stages in zoospore development and discharge. See text for full explanation. × 1216.

Fig. 9. Section of resting sporangium in same stage as in fig. 4, showing spores polygonal from pressure, nucleus as a clear sphere (n), partly covered by nuclear cap (n.c.), with eight to ten lipoid granules (l. g.). Drawn from living material, semi diagrammatic. × 2240.

Fig. 10. Sketch of living motile zoospore, labels as in fig. 9. × 2240.

Fig. 11. Zoospores killed with osmic acid fumes and stained with dilute gentian violet, showing whiplash flagellum, nucleus, nuclear cap and lipoid granules. × 2240.

PLATE 16

Fig. 1. Resting sporangia of *Coelomomyces dodgei* on *Anopheles crucians*, showing wall with pits and bands. Valdosta (M6), Ga., Sept. 17, 1945. × 700.
Fig. 2. *C. lativittatus*, with wide bands, on *A. crucians*. Thomasville (H14), Ga. × 700.
Figs. 3, 4. *C. lativittatus* on *A. crucians*. Moultrie (S14), Ga., March 28, 1945. × 700
Fig. 5. *C. punctatus* on *A. quadrimaculatus*. Dublin (C201), Ga., July 21, 1945. × 700.
Fig. 6. *C. punctatus*. Moultrie (T1d2), Ga. April 11, 1945. × 700.

PLATE 17

Fig. 1. *Coelomomyces sculptosporus* on *Anopheles punctipennis*, showing various markings on wall. Macon (F5), Ga., June 9, 1945. × 700.
Fig. 2. *C. sculptosporus* on *A. punctipennis*. Rome (C57), Ga., July 4, 1945. × 700.
Fig. 3. *C. cribrosus* on *A. crucians*. Rome (C55), Ga., Aug. 23, 1945. × 700.
Fig. 4. *C. uranotaeniae* on *U. sapphirina*, showing mycelium and resting sporangia. × 700.
Figs. 5-7. Several views of resting sporangia of *C. bisymmetricus*. Moultrie (S22), Ga. 6, × 1050; 5, 7, × 700.

PLATE 18

Fig. 1. Resting sporangium of *C. bisymmetricus* in face view, showing concentric bands: Moultrie (C137), Ga., April 13, 1945. × 1050.
Fig. 2. Same in side view. × 1050.
Fig. 3. Same in cross section view. × 1050.
Fig. 4. Same in longitudinal section view, showing section of wall. × 1400.
Fig. 5. Wall surface of *C. cribrosus*, showing irregular thin areas. On *Anopheles crucians*, Rome (C55), Ga., Aug. 23, 1945. × 1050.
Figs. 6-8. *C. sculptosporus*. Three photographs of same resting sporangium: upper showing side of wall with longitudinal bands; middle, longitudinal section; lower focussed on lower inner surface of outer layer of wall, showing irregular bands. On *A. crucians*, Thomasville (C400), Ga., March 27, 1945. All × 1050.
Fig. 9. *C. sculptosporus*, same material as above. Upper resting sporangium with rounded pores; lower of same type but showing the one longitudinal band with preformed lengthwise dehiscence slit. × 1050.

PLATE 19

Fig. 1. Characteristically branched piece of mycelium of *C. pentangulatus* in haemocoel of *Culex erraticus*. This will break up into naked segments that develop into resting sporangia. Valdosta, Ga., Oct. 1944. × 700.
Fig. 2. Mycelium and young and mature resting sporangia of *C. quadrangulatus*. On *A. punctipennis*. Type, Georgia, Nov. 1944. × 200.
Fig. 3. Mycelium of *C. quadrangulatus*. Type. × 700.
Fig. 4. Mycelium and a few resting sporangia of *C. quadrangulatus* var. *irregularis*. On *A. punctipennis*. Dublin (C9), Ga. × 200.
Fig. 5. Resting sporangia of *C. quadrangulatus* var. *irregularis*. Same collection as above. × 1050.
Fig. 6. Resting sporangia of *C. quadrangulatus* on *A. punctipennis*. Georgia. × 400.

PLATE 20

Fig. 1. Part of hypha of *C. dodgei* about to cut off a hyphal body that will develop into a sporangium. Note granular appearance of plasma membrane in lower part. On *A. crucians*, Valdosta (M21 and 22), Ga., Dec. 7, 1944. × 1400.
Fig. 2. Enlarged branching end of hypha of *C. keilini*, perhaps getting ready to cut off two hyphal bodies. Note indications of membrane at right. Type. On *A. crucians*, Valdosta (M21 and 22), Ga., Dec. 7, 1944.

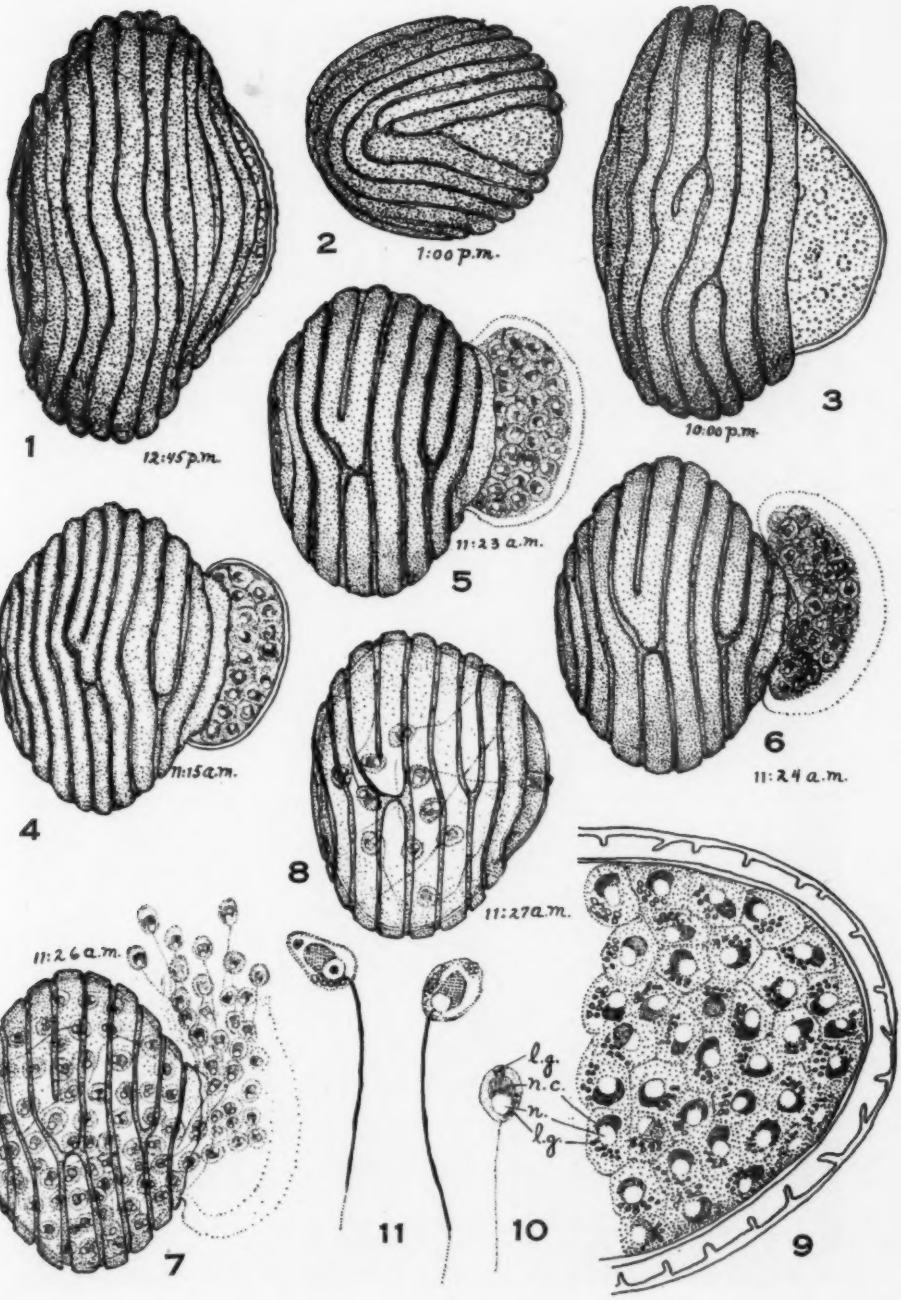
Fig. 3. Mass of hyphae, several of which have dichotomous branches, also resting sporangia in various stages. Type. × 200.

Fig. 4. Longitudinal section of mature resting sporangium of *C. keilini*. Type. × 1050.

Fig. 5. Surface view of resting sporangium of *C. keilini*, showing star-shaped pits in outer wall. Type. × 1050.

Fig. 6. Prosori and empty sporangial sori of *Micromyces longispinosus* parasitic in Spirogyra threads eaten by larvae of *A. crucians* and found in larva's gut. Thomasville (C86), Ga.

PLATE 15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7
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l.g.
n.c.
n.
l.g.
11

PLATE 16

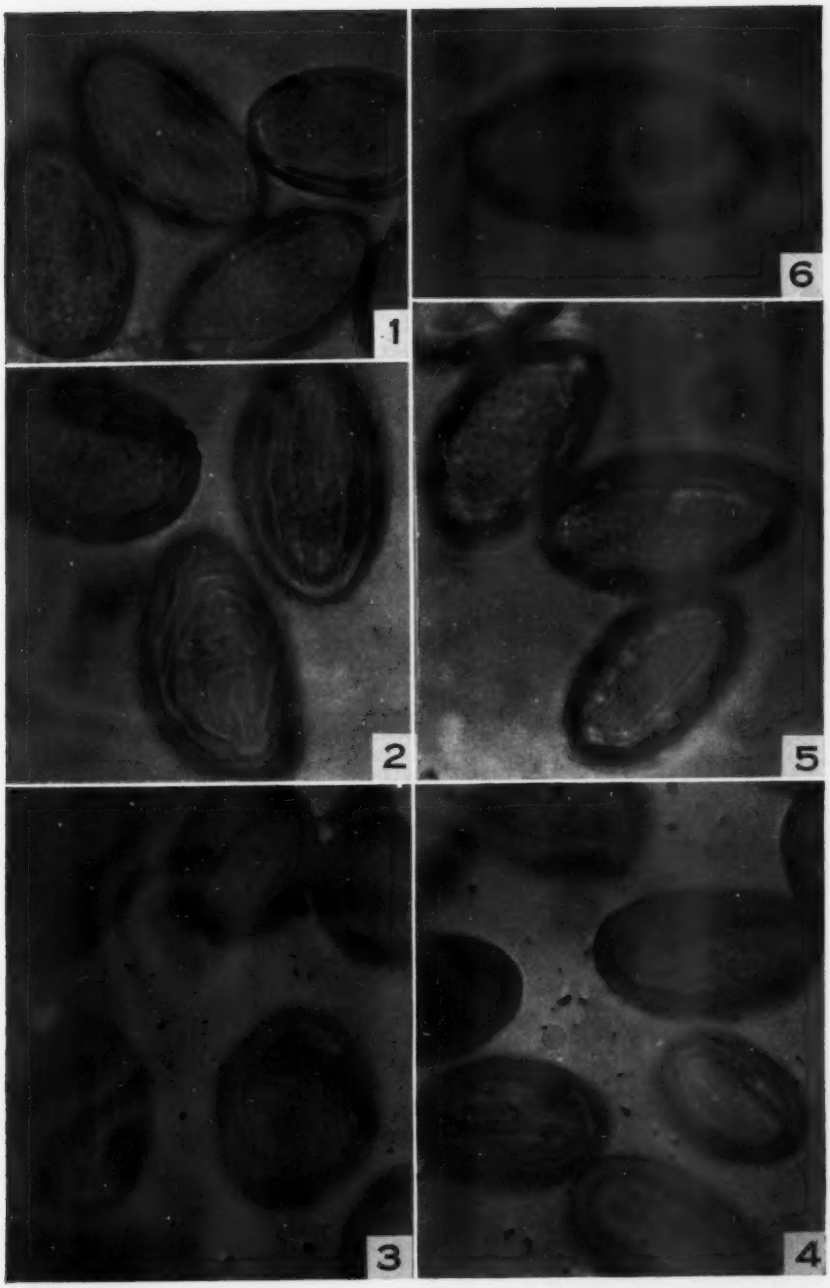


PLATE 17

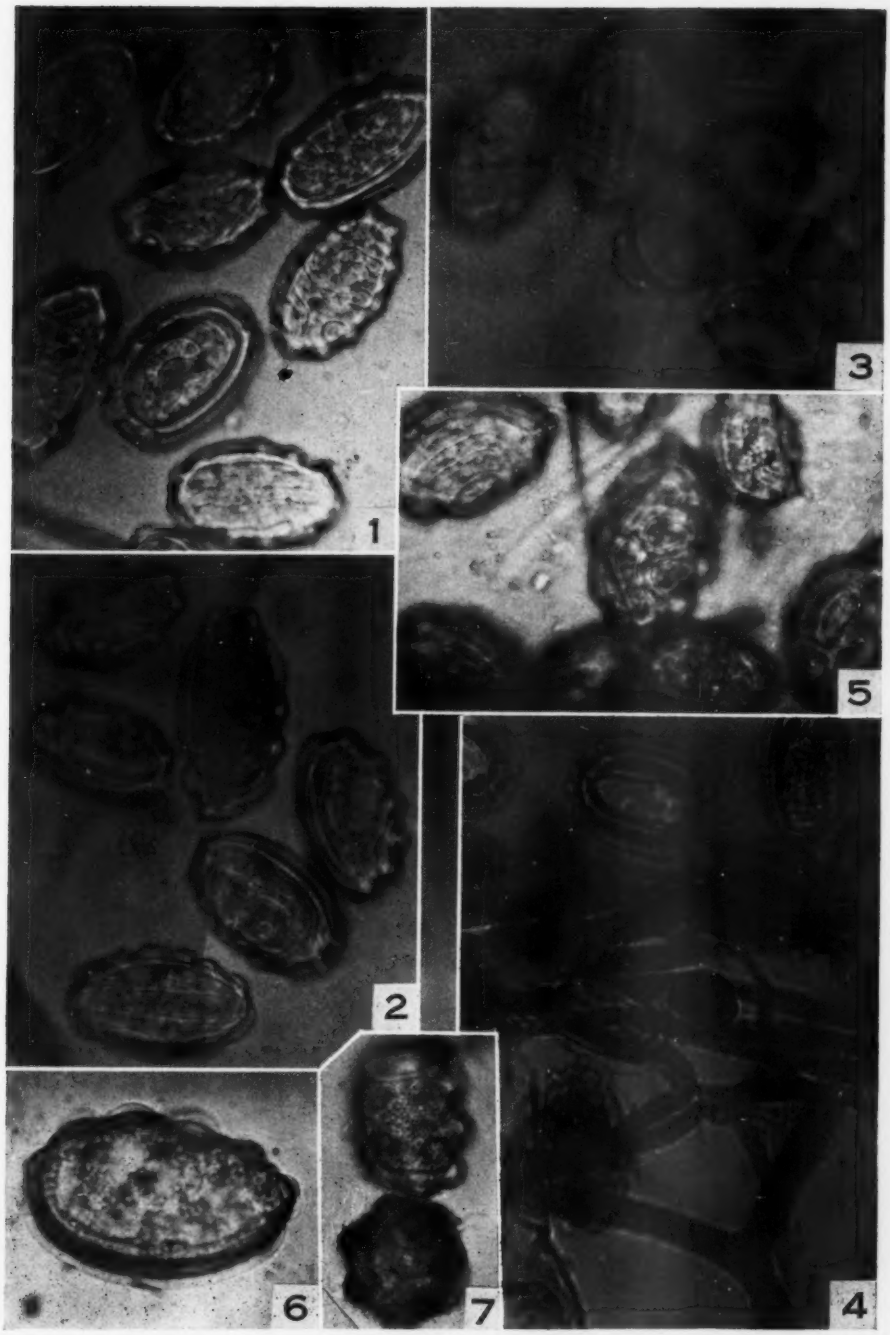


PLATE 18

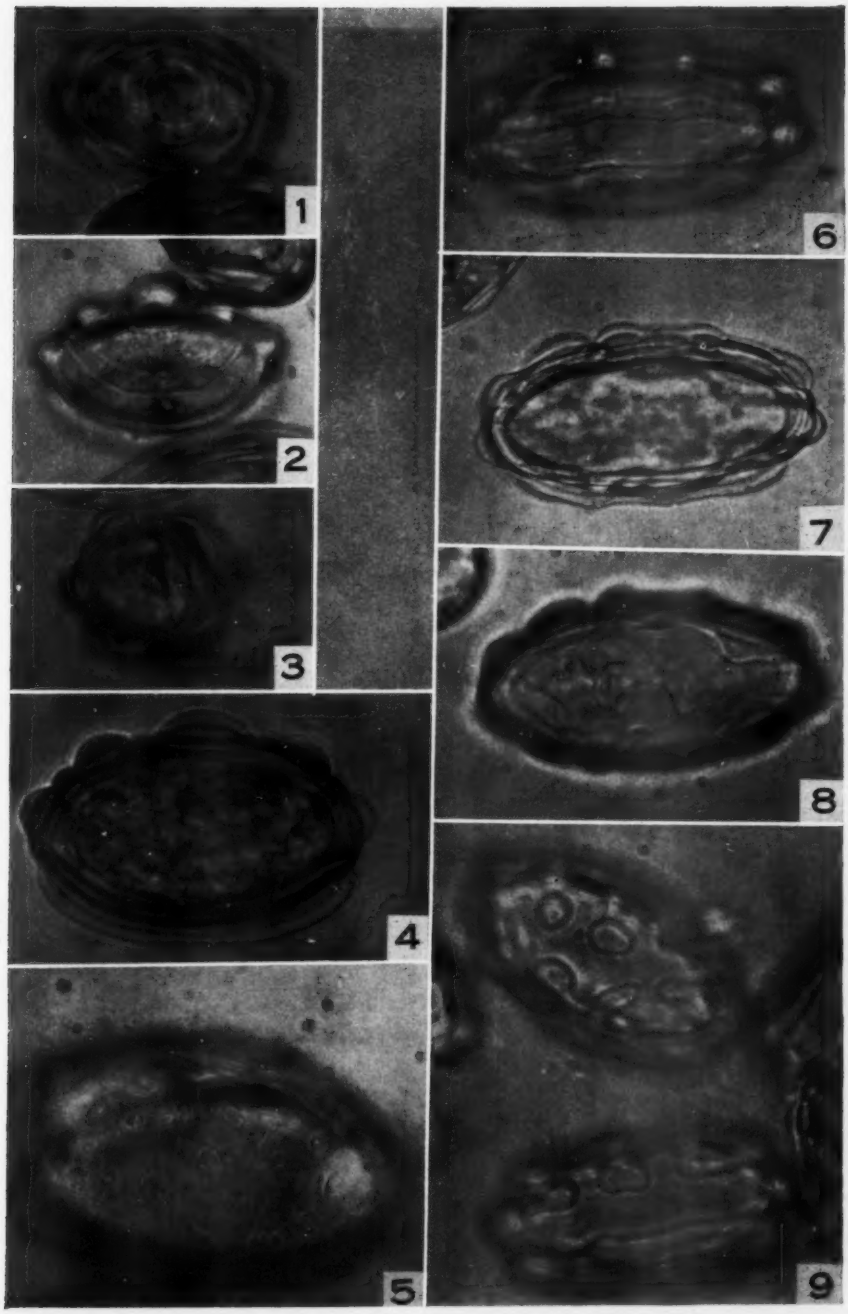


PLATE 19

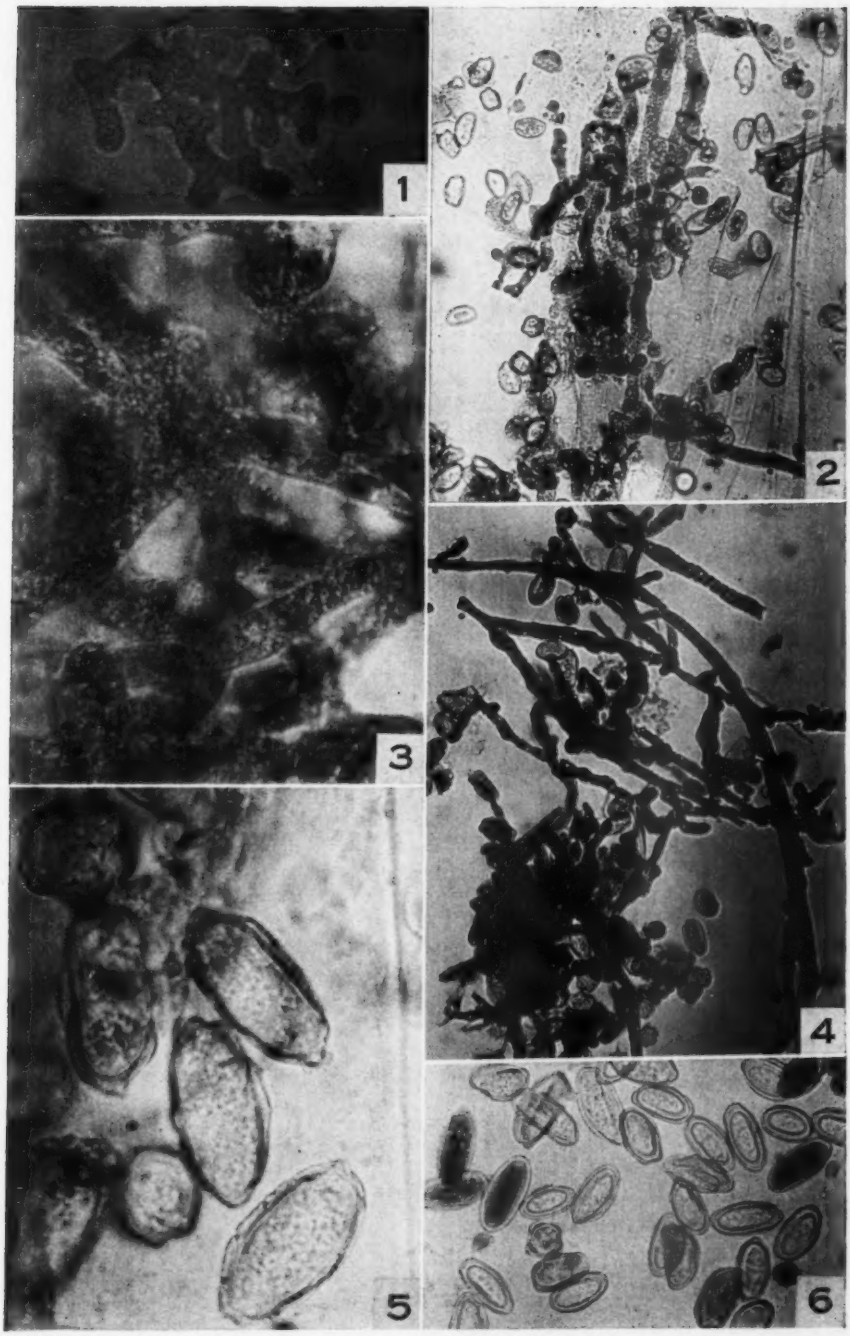
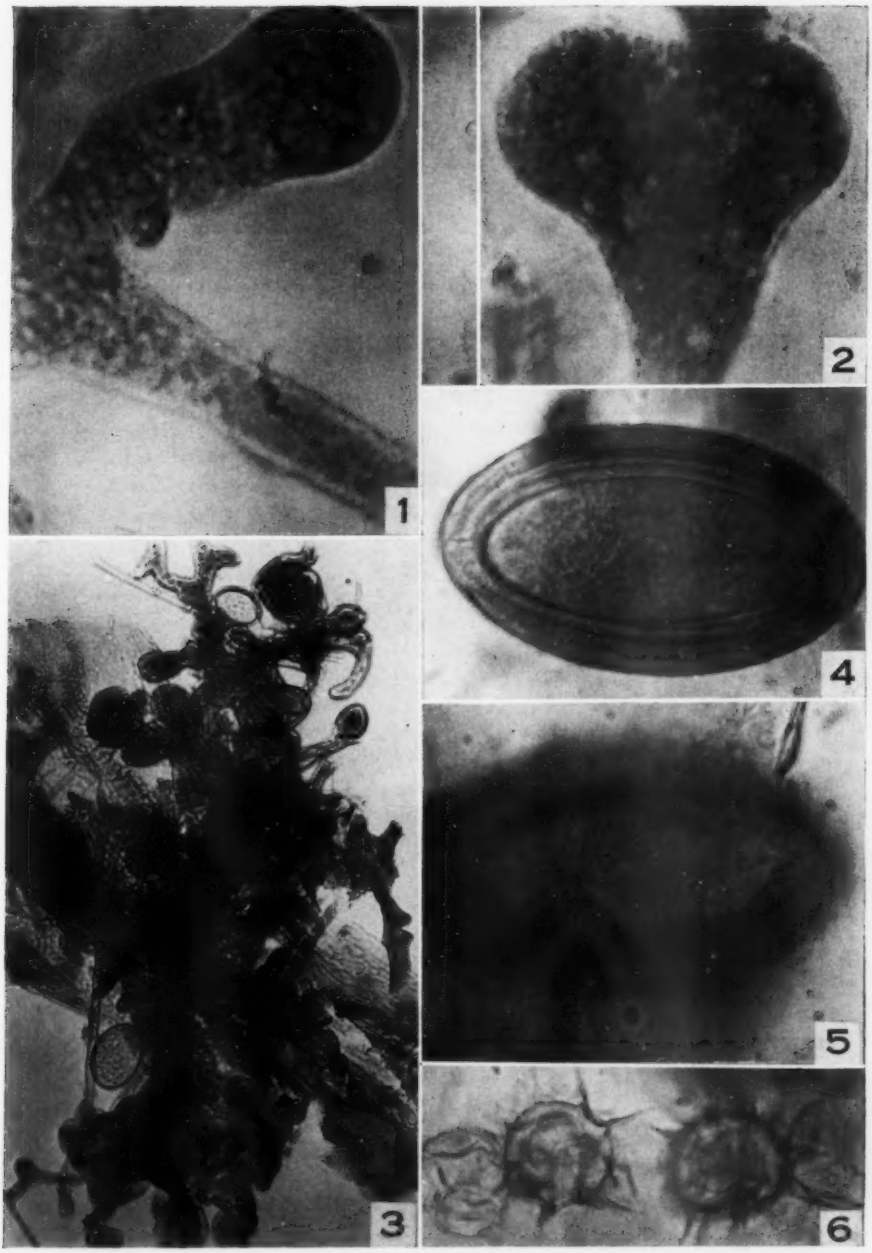


PLATE 20



CALLINECTES VERSUS OSTREA

By G. Robert Lunz, Jr.

Bears Bluff Laboratories

Wadmalaw Island, South Carolina

The Blue Crab is perhaps the most serious oyster pest encountered at Bears Bluff Laboratories where the Charleston Museum is successfully carrying out experiments on the cultivation of oysters in ponds. Oyster mortality from the depredations of crabs has been greater than from all other causes combined.

The greatest mortality has been among the young oysters from 5 to 30 mm. in diameter but only the thick-shelled, hard, old oysters are immune and even they perhaps are not entirely so. Spat collected on cement dipped cardboard partitions[1] are particularly susceptible and within 24 hours 90% of the spat on such a partition can be and often are destroyed. The crabs simply cling to the partition and with either or both chelipeds chew off the partition bit by bit until the young oyster is reached. This is then cracked and eaten. Over 80% of the young oysters collected on partitions during the spawning season of 1946 were destroyed in this way and it became necessary to build a fenced-in pen within the experimental pond to protect the young oysters.

Callinectes does not confine its efforts to these young tender oysters. A bushel of oysters taken off wharf piling in a small creek near the Laboratory were placed in one of the ponds. A few days later it was noticed that these oysters were scattered and quite a few had been broken open. At first, the blame was put on either raccoons, minks, or otters, the first two of which are quite common around the Laboratory. However, a few days of constant checking soon showed that crabs were responsible for the damage. At a dozen different times large crabs 6 inches across the carapace were watched at work on the oysters. The crab would hold the oyster with one cheliped and gradually crack off the thin growing edges of the oyster. The process was slow but certain for the crab. Gradually piece by piece the bill of the oyster was cracked off until the edge of the mantle of the oyster was exposed. Once this far the crab made better headway and within a short time the oyster was completely opened, the shell cracked up and the meat eaten. From January 17 to April 1, even during a time when crabs are scarce and inactive because of low temperatures, about 50% of the bushel of oysters were destroyed.

It is to be understood that these particular oysters were of the cluster variety, thin-shelled and elongated and thus perhaps an easier prey for the crabs. However, on several occasions large crabs have been noted working on hard-shelled, large oysters. Just how successful they are at opening a tough old oyster is not known but several such specimens have been found dead and showing evidence that crabs had been working on them.

[1] For details see: Prytherch, H. F., Improved Methods for the Collection of Seed Oysters, Bur. Fisheries Doc. 1076, Appendix IV, U. S. Comm. of Fisheries for 1930.

BOOKS FROM CHAPEL HILL

THE BOLETACEAE OF NORTH CAROLINA. By WILLIAM CHAMBERS COKER AND ALMA HOLLAND BEERS. This study is based on notes and photographs taken by the senior author over a period of about forty years. For a good many years both authors have worked on the group and have made many collections. While most of the work has been done in Orange County and in the Blue Ridge and Alleghany Mountains of North Carolina, many specimens have been collected in South Carolina and Georgia. While the title covers only North Carolina, this work includes all except the few species reported from the neighboring states of Virginia, South Carolina, Georgia, and Alabama of which examples have not been available or that have been reduced to synonomy with species included.

There are described under the genus *Boletus* sixty-eight species and six varieties. Of these, three species and four varieties are described as new. Four species of *Boletinus* and one of *Strobilomyces* are also included. Twenty species are illustrated in color and nearly all of the others by halftone photographs.

There are 96 pages of text; 6 colored plates; 55 halftone plates; and 5 plates of line drawings showing microscopic details. $7.00.

GROWING PASTURES IN THE SOUTH. By J. F. COMBS. Better pastures and grazing lands in the South will aid greatly in bringing about a more profitable and enduring type of agriculture, and will help to overcome the disastrous one-crop system of many southern communities. This book is not only an attempt to create greater interest in pasture improvement; it also furnishes the farmer and cattleman with detailed and practical information on how to develop pasture areas into profitable grazing lands; it contains enough technical information to make it useful as a text. Mr. Combs is a pasture crop specialist who for seventeen years has been Agricultural Extension Agent for the United States Department of Agriculture and A. &. M. College of Texas. Seventy-eight illustrations, nine tables. About 280 pages. Size 5½″ x 8¼″. $2.00.

PRACTICAL FARMING FOR THE SOUTH. By BENJAMIN F. BULLOCK. A useful guide to practical farming, containing step-by-step directions for performing all necessary tasks on the small farm. Of especial value to rural teachers and leaders, vocational agricultural students, 4-H club members, small farmers, part-time or subsistence farmers, and to any others who are directly concerned with the problems of increased food production and of achieving a more abundant farm life. February, 1944. $2.50.

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